# The American Journal of Surgery

EDITED BY THURSTON SCOTT WELTON, M.D., F.A.C.S.

March 1941

## TRAUMATIC SURGERY

Papers Read at the June 1940
Meeting of The American Association
for the Surgery of Trauma

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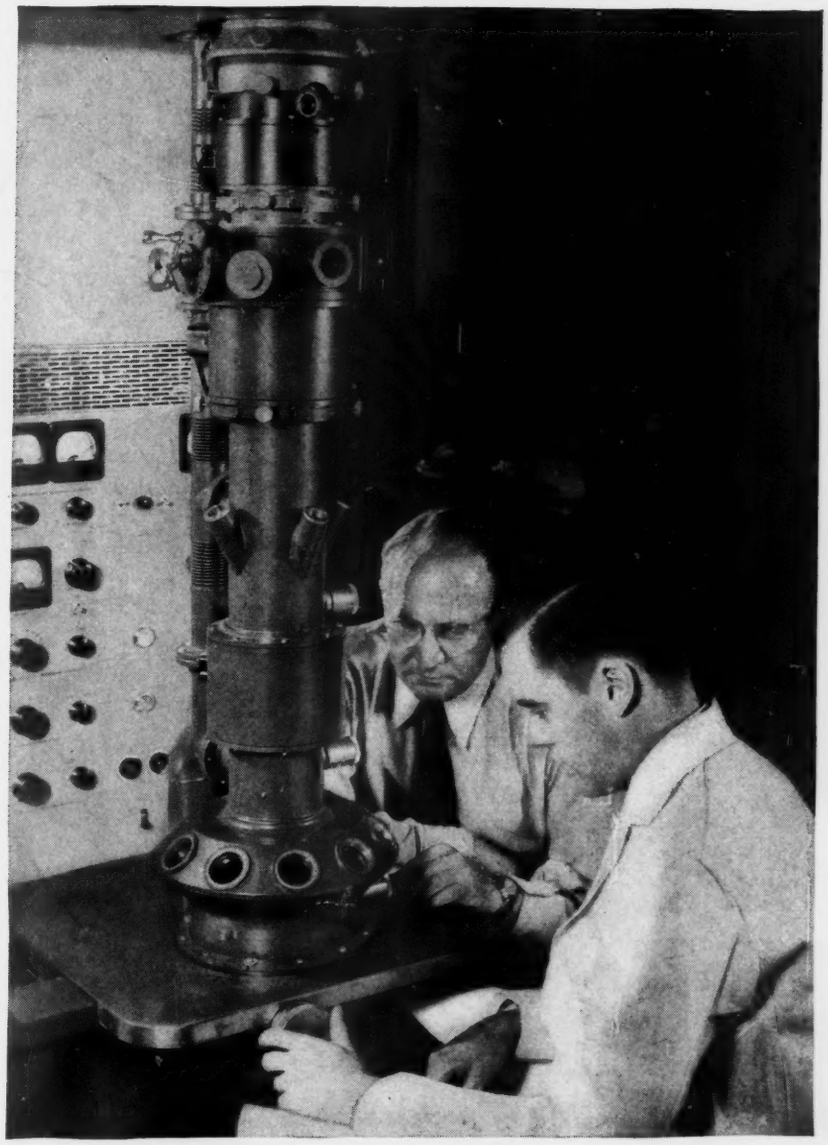
# A New Aid to Suture Research



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FIFTY TIMES more powerful than the strongest optical microscope and providing useful magnification up to 100,000 diameters, the recently perfected electron microscope has greatly extended the horizon of scientific observation.

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*Further details of the Electron Microscope are given on the third page following*

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# D&G Sutures

**NOTE: In agreement with the new U. S. P. nomenclature, catgut products formerly known as Plain, 10-day, 20-day, and 40-day, are now designated as**

**Plain – type A** | **Medium chromic – type C**

**Mild chromic – type B** | **Extra chromic – type D**

THERE HAS BEEN NO CHANGE IN THE PRODUCTS THEMSELVES

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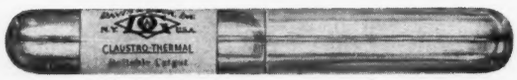


POSSESSES all the qualities essential to proper function and is adaptable to all conditions and technics. The tubes may be boiled or autoclaved for asepticization of their outer surface or treated germicidally.

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| NO. | | LENGTH *in excess of* | SIZES |
|---|---|---|---|
| 1205 | Plain—type A | 54″ | 5-0 to 4 |
| 1225 | Mild chromic—type B | 54″ | 4-0 to 4 |
| 1245 | Medium " —type C | 54″ | 4-0 to 4 |
| 1285 | Extra " —type D | 54″ | 4-0 to 4 |

Package of 12 tubes of a kind $3.60

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|---|---|---|---|
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| 1425 | Mild chromic—type B | 54″ | 4-0 to 4 |
| 1445 | Medium " —type C | 54″ | 4-0 to 4 |
| 1485 | Extra " —type D | 54″ | 4-0 to 4 |

Package of 12 tubes of a kind $3.60

## Kal-dermic Sutures

KAL-DERMIC★ represents the culmination of eight years' research to perfect a skin and tension suture combining the best features, while eliminating the disadvantages of silkworm gut, horsehair, silk and several synthetic products variously named.

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| NO. | NEEDLE | LENGTH | SIZES | PER BOX |
|---|---|---|---|---|
| 550 | None | 2 x 60″ | 4-0 to 0 | $3.60 |
| 953 | ⅜-circle | 20″ | 000, 00, 0 | 3.00 |
| 954 | Half-curved | 20″ | 000, 00, 0 | 3.00 |
| 852 | None | 40″ | 8-0, 6-0, 4-0 to 0 | 1.80 |

**On reels, unsterilized**
(Ten reels to a box)

| | | | | NET, PER DOZ. BOXES |
|---|---|---|---|---|
| 50 | None | 190″ | 0000 | $10.50 |
| | | | 000 | 11.64 |
| | | | 00 | 12.60 |
| | | | 0 | 14.40 |

### KAL-DERMIC TENSION SUTURES

**In tubes, sterilized**
(Twelve tubes to a box)

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|---|---|---|---|---|
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| 855 | None | 20″ | 1, 2, 3 | 1.80 |

**On reels, unsterilized**
(Ten reels to a box)

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|---|---|---|---|---|
| 50341 | Straight | 28″ | 5-0 | $3.60 |
| 50344 | Half-circle | 28″ | 5-0 | 4.20 |
| 50245 | None | 54″ | 5-0 | 3.60 |
| 40341 | Straight | 28″ | 4-0 | 3.60 |
| 40344 | Half-circle | 28″ | 4-0 | 4.20 |
| 40245 | None | 54″ | 4-0 | 3.60 |

THERMO-FLEX (*non-boilable*)

| | | | | |
|---|---|---|---|---|
| 50541 | Straight | 28″ | 5-0 | $3.60 |
| 50544 | Half-circle | 28″ | 5-0 | 4.20 |
| 50445 | None | 54″ | 5-0 | 3.60 |
| 40541 | Straight | 28″ | 4-0 | 3.60 |
| 40544 | Half-circle | 28″ | 4-0 | 4.20 |
| 40445 | None | 54″ | 4-0 | 3.60 |

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## Anacap Silk

NEW principles of fabrication provide ANACAP★ silk with unprecedented strength, knot security, and absolute non-capillarity.

| NO. | LENGTH | SIZES | DOZEN |
|---|---|---|---|
| A40 | 40″ | 8-0, 6-0, 4-0 to 4 | $1.80 |
| A120 | 2 x 60″ | 8-0, 6-0, 4-0 to 4 | 3.60 |

Packages of 12 tubes of a kind and size

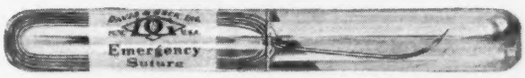
## Unabsorbable Sutures

| NO. | MATERIAL | LENGTH | SIZES |
|---|---|---|---|
| 350 | Celluloid-linen | 60″ | 000, 00, 0 |
| 360 | Horsehair | 6 x 28″ | 00 |
| 390 | White silkworm gut | 6 x 14″ | 00, 0, 1 |
| 400 | Black silkworm gut | 6 x 14″ | 00, 0, 1 |
| 450 | White twisted silk | 60″ | 000 to 3 |
| 460 | Black twisted silk | 60″ | 000 to 2 |
| 480 | White braided silk | 60″ | 00, 0, 2, 4 |

Packages of 12 tubes of a kind $3.60

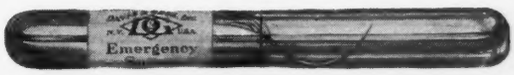
## Emergency Kit Sutures

THREADED on half-curved or 3/8-circle eyed needles with cutting edges for skin, muscle, or tendon. Heat sterilized in glass tubes which may be either boiled or submersed in any active germicidal solution to asepticize their outer surface.




WITH HALF-CURVED NEEDLES

| NO. | MATERIAL | LENGTH *in excess of* | SIZES |
|---|---|---|---|
| 904 | Plain—type A catgut | 18″ | 00 to 3 |
| 914 | Mild chromic—type B | 18″ | 00 to 3 |
| 924 | Medium chromic—type C | 18″ | 00 to 3 |
| 954 | Kal-dermic | 20″ | 000, 00, 0 |
| 964 | Horsehair | 2 x 28″ | 00 |
| 974 | White silkworm gut | 2 x 14″ | 00, 0 |
| 984 | White twisted silk | 20″ | 000, 0, 2 |
| 986 | Anacap silk | 20″ | 000, 0, 2 |
| 900 | Assorted: Catgut, Silk, and Kal dermic | | |




WITH 3/8-CIRCLE NEEDLES

| | | | |
|---|---|---|---|
| 903 | Plain—type A catgut | 18″ | 00 to 2 |
| 923 | Medium chromic—type C | 18″ | 00 to 2 |
| 953 | Kal-dermic | 20″ | 000, 00, 0 |
| 963 | Horsehair | 2 x 28″ | 00 |
| 973 | White silkworm gut | 2 x 14″ | 0 |
| 983 | White twisted silk | 20″ | 000, 0, 2 |
| 985 | Anacap silk | 20″ | 000, 0, 2 |
| 930 | Assorted: Catgut, Silk, and Kal-dermic | | |

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## Other D & G Sutures

IN ADDITION to the foregoing a wide variety of suture-and-needle combinations is available for intestinal, thyroid, tonsil, eye, harelip, cleft palate, plastic, nerve, artery, obstetrical, circumcision, ureteral, renal and dental surgery. A complete list of sizes, lengths, needle combinations, etc. will be supplied on request.

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# A New Aid to Suture Research

## *The Electron Microscope*

FOR SOME YEARS it appeared that an impasse had been reached in the extension of microscopic observation. The ability to penetrate smaller and smaller fields depends not upon greater magnification—which is limitless—but upon increased resolving power, or the power of discriminating between minute objects in close proximity. Since resolution is definitely limited to the wave length of the medium of illumination employed, the maximum efficiency of the optical or light microscope was attained when it was adapted to the use of short wave ultra-violet radiation.

Efforts to explore beyond the limits of the microscope, therefore, turned to indirect methods until it was observed that a close analogy exists between the action of a glass lens on a light beam and that of an electro-magnetic field on an electron beam. This suggested the development of an instrument which, in place of light, would utilize electronic emanations of infinitesimal wave length. The outcome was the electron microscope.

IN GENERAL PRINCIPLE and in arrangement of its essential elements this instrument is quite similar to the light microscope. The electron beam is condensed, passed through the specimen, enlarged and focused upon a fluorescent screen for direct observation or upon a photographic plate as desired.

Manipulation of the electron microscope differs from that of the light microscope in that focusing is done by varying the lens power instead of changing the position of the specimen with respect to the lens. This is possible because in magnetic optics "lenses" are created and controlled by current flowing through a coil. Ability to vary the lens power also permits continuous variation of magnifying power —a marked advantage over the step by step method of the light microscope.

THE PERFORMANCE of the present instrument conclusively demonstrates its practicability and great immediate value. It permits direct observation in magnifications up to 30,000 diameters and photographic magnifications up to 100,000 diameters. Moreover, many specimens transparent to light are shown in detail by the electron beam without recourse to staining.

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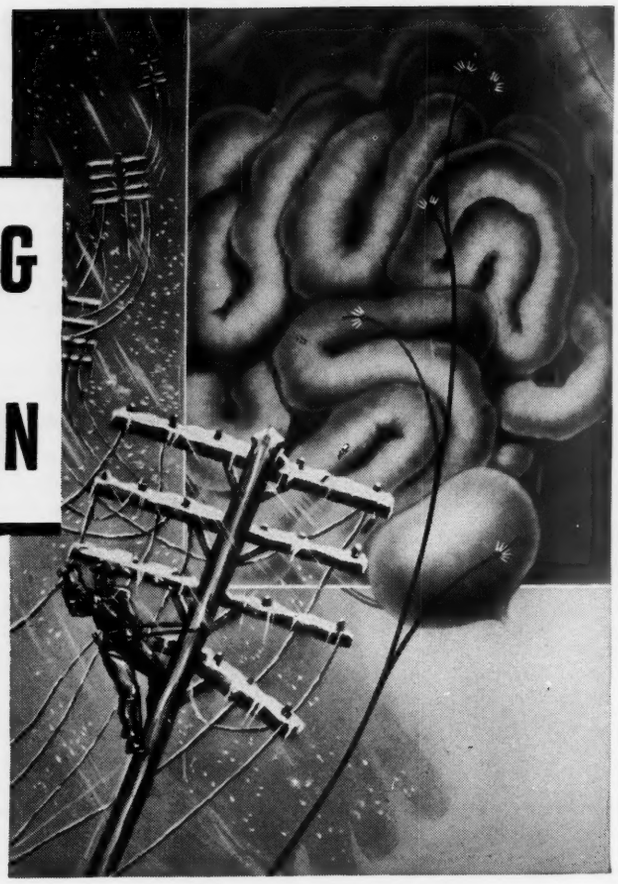

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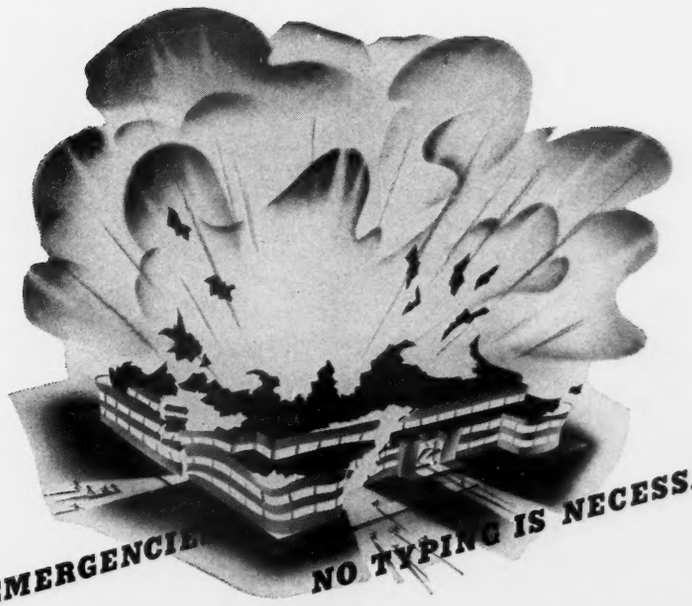

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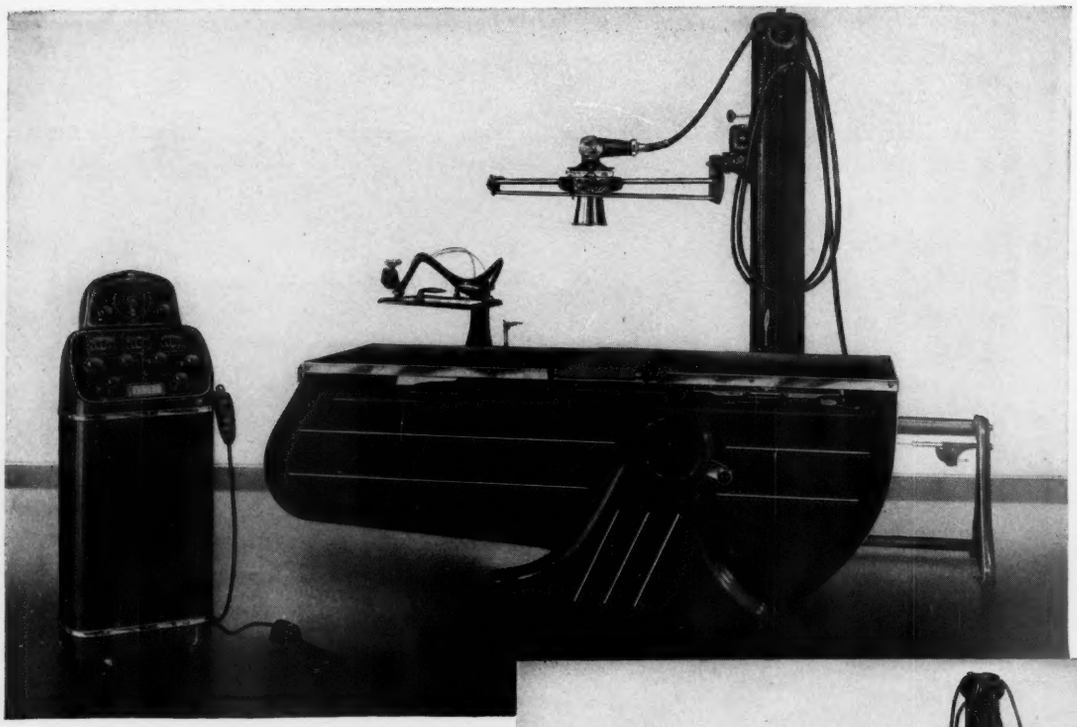

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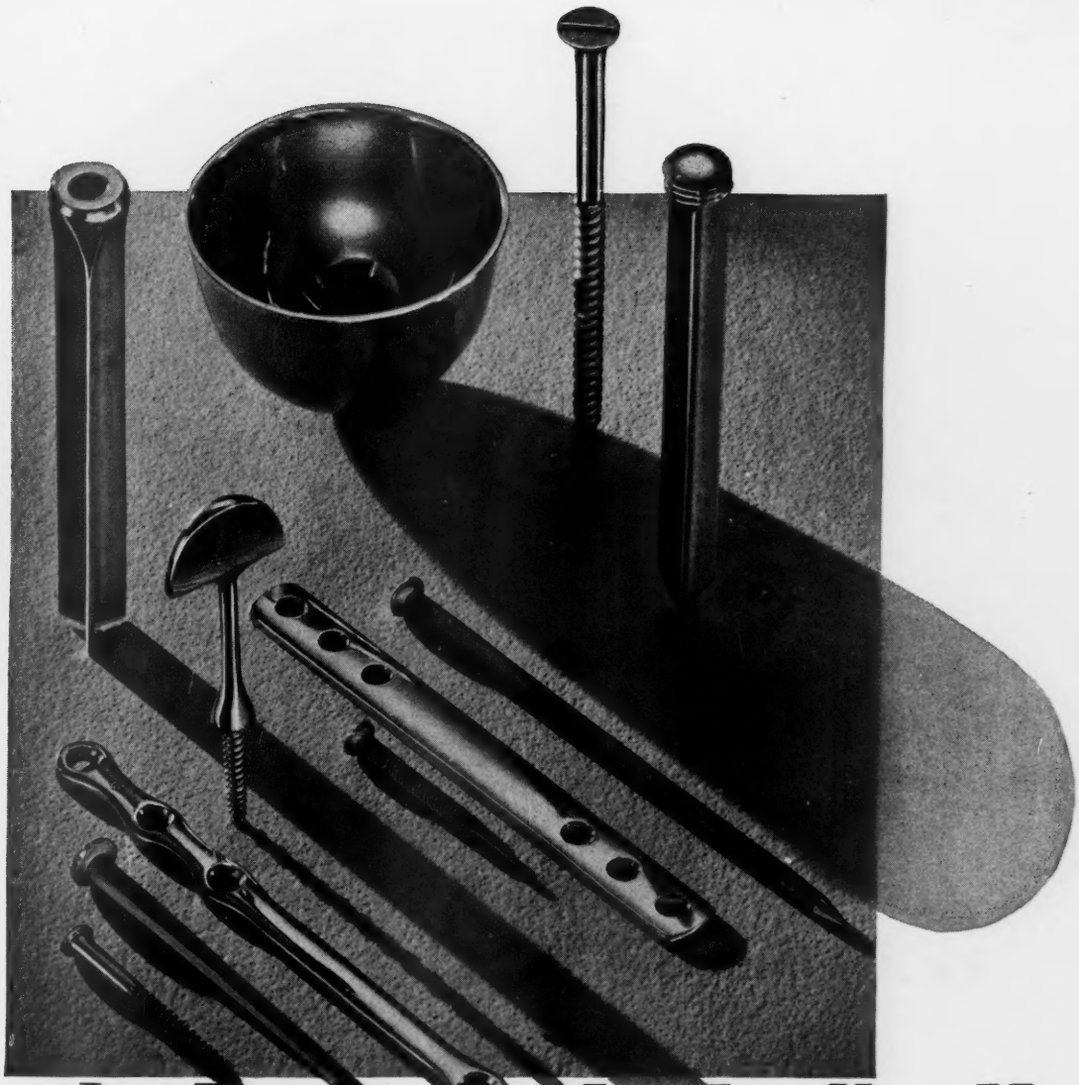

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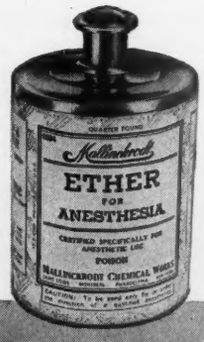


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[1] Sevringhaus, E. L., and Evans, J. S.: *Am. J. M. Sc.* 178:638, Nov. 1929.
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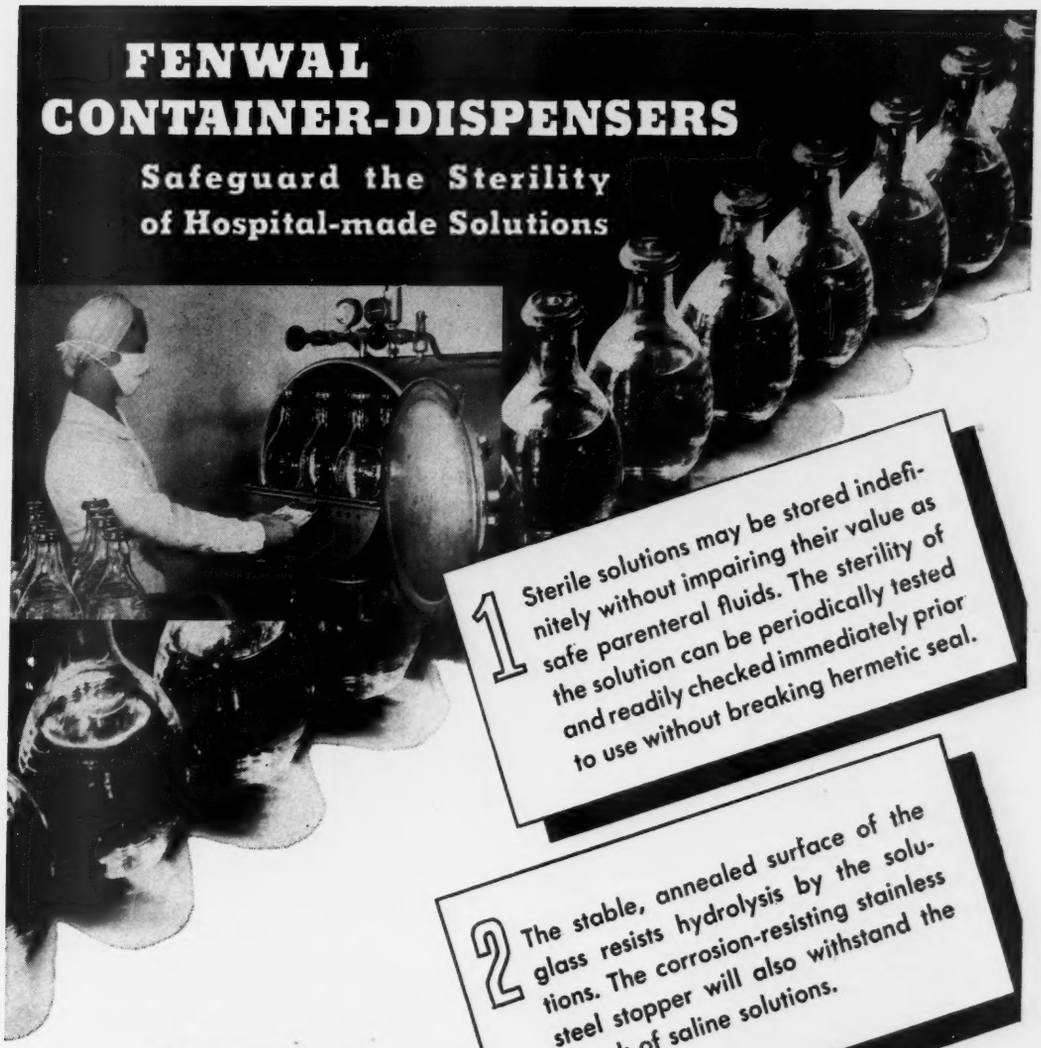

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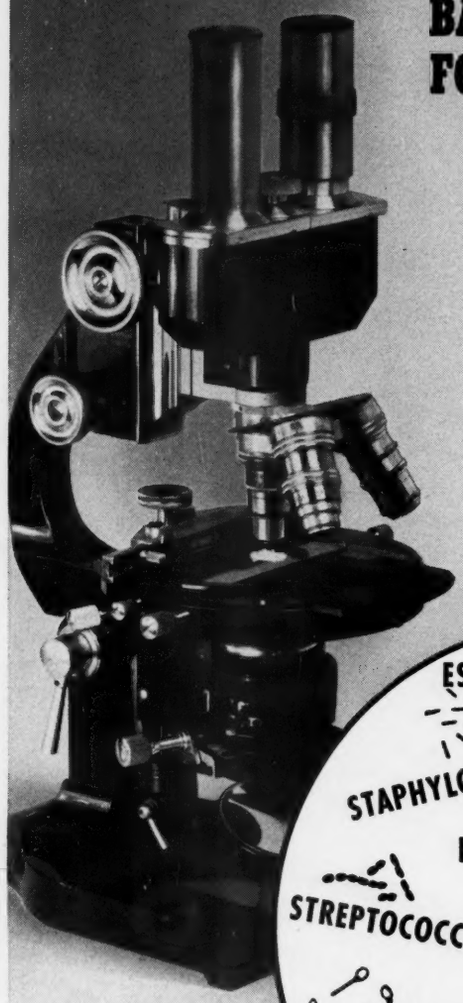

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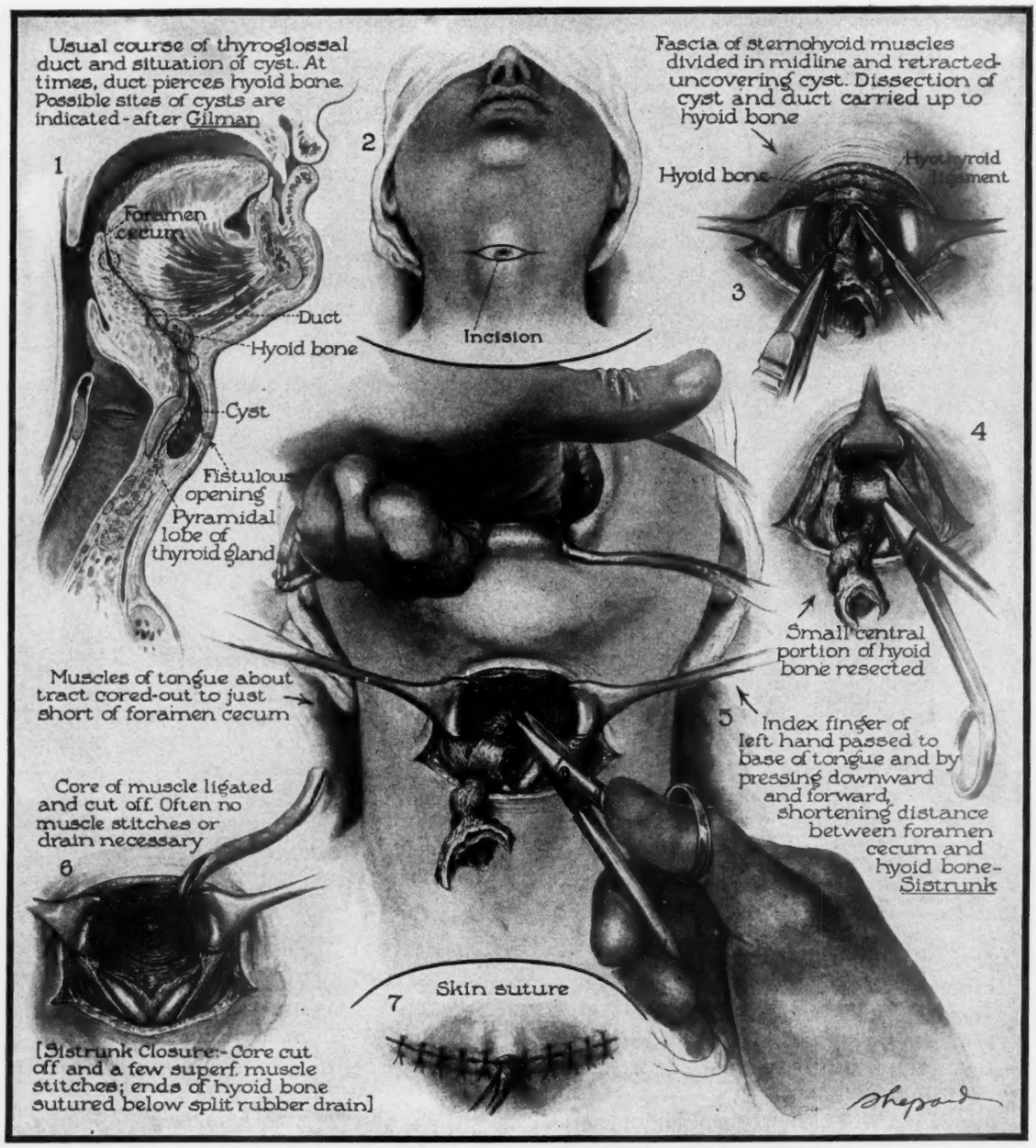
Usual course of thyroglossal duct and situation of cyst. At times, duct pierces hyoid bone. Possible sites of cysts are indicated - after Gilman
1
Foramen cecum
Duct
Hyoid bone
Cyst
Fistulous opening
Pyramidal lobe of thyroid gland
2
Incision
Fascia of sternohyoid muscles divided in midline and retracted uncovering cyst. Dissection of cyst and duct carried up to hyoid bone
Hyoid bone
Hyothyroid ligament
3
4
Small central portion of hyoid bone resected
Muscles of tongue about tract cored-out to just short of foramen cecum
5
Index finger of left hand passed to base of tongue and by pressing downward and forward, shortening distance between foramen cecum and hyoid bone - Sistrunk
Core of muscle ligated and cut off. Often no muscle stitches or drain necessary
6
7
Skin suture
[Sistrunk Closure:- Core cut off and a few superf. muscle stitches; ends of hyoid bone sutured below split rubber drain]
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# Editorial

## THE PROGRESS OF THE SURGERY OF TRAUMA*

PRESIDENTIAL ADDRESS

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THERE never was a time when we stood more in need of a ready and sound knowledge of the cardinal principles of the surgery of trauma than at present. With a great part of the world at war and with our not knowing when an incident may happen which may precipitate our entry into the collossal maelstrom, it is timely for a group of outstanding surgeons to gather and discuss the progress of the surgery of trauma. The far-reaching effects of the good that this association may accomplish can not be estimated at this time.

They are wrong who say that today there are no new surgical frontiers! Growth for a science is not measured by topographical boundaries, but by the expanding needs of our social and economic life.

The opportunities and rewards for the surgery of trauma are greater today than ever because, within the memory of living man, the wilderness has been transformed into great centers of trade and industrial activity. We have ceased trickling through forest trails or trudging over dirt roads in ox-carts or with horse and buggy.

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Our civilization has demanded fast transportation and now we speed in highpowered cars over paved roads, in streamlined trains along highways of steel and in commodious planes through the airways of the world. We are, indeed, living today in an age of speed.

The surgeon, always the pioneer, has met with ingenuity and resourcefulness the often disastrous human consequences of these demands of our civilization. What are the pressing and urgent needs today? Well may we pause and reflect on this problem. Today accidents rank fourth—behind only heart disease, cancer and pneumonia —as causes of death among mankind. Never since the world began has there been such a need for surgeons profoundly interested in the broad subject of trauma. In the United States alone, in a year 9,000,000 people are injured, 8,300,000 are temporarily disabled, 330,000 are permanently disabled, and 93,000 die from accidents. The indications are that these figures will increase this year.

Of these fatalities, 34 per cent are the result of motor vehicle accidents, 33 per cent the result of home accidents, 18 per cent the result of occupational accidents, and 15 per cent the result of public accidents of various sorts. Motor vehicle deaths have increased tremendously in the past twenty-five years while the number of industrial fatalities has been lessened 50 per cent. At the present rate, one person in twenty will be injured in an automobile accident in the next five years and there will be at least one fatality for each thirty-five such accidents. The National Safety Council reported that 7,200 persons were killed in motor vehicle accidents in the United States during the first quarter of this year, 450, or 7 per cent, more than in the same period last year. Compared with other types, industrial accidents, contrary to the usual opinion, involve a far smaller number of casualties, fatal or otherwise. A total of 9,000,000 persons killed or injured by accidents during the year represents approximately one-twelfth of our country's population.

Our nation, since its birth in 1775, has engaged in six major wars. In total, these wars extended over a period of fifteen years. The number of American soldiers killed in action or who died of wounds during those fifteen years of war was 244,357 as compared with 456,281 who were killed on the highways during the past fifteen years of peace. Therefore, this national traffic death toll is almost double that of war. Indeed, our American highways have become more dangerous to the nation as a whole than is a battlefield.

Today the problem is larger than any war has yet presented. From the Adjutant General's Office of the War Department comes the record of 143 years:

U.S.A. WARS RECORD

| War | Killed in Action and Died of Wounds |
|---|---|
| Revolutionary War | 4,044 |
| War of 1812 | 1,956 |
| War with Mexico | 1,549 |
| Civil War (Union Forces) | 110,070 |
| Civil War (Confederate Forces) | 74,524 |
| War with Spain (including Philippines) | 1,704 |
| World War I | 50,510 |
| Total | 244,357 |

The economic loss caused by accidents in one year is appalling. While one can not and should not attempt to compute the value of human life and limb and crippling in dollars and cents, yet the economic loss is a real and tangible factor and amounted last year to about $3,330,000,000.

A few years ago it occurred to a few of us that the subject of the surgery of trauma was not receiving the study it demanded. The specialties of late years had become so restricted that various factors, namely shock, infection, biochemistry of traumatized tissues and the mechanical and surgical problems involved in different injuries to various parts and organs of the body were often being subordinated in the constriction of the field to a single part of the body. We reviewed the programs for the past five years of the leading surgical associations in America and found that less than 10 per cent of the total number of papers read before these associations were concerned with trauma. To fill a long-felt need, therefore, and not just to form another society, of which we realize there are plenty, this association was brought into being in 1938. As my illustrious predecessor said last year in his presidential address: "We are calling back into the fold the well trained general surgeon interested in the maintenance of high surgical skill and scientific development in the phases of surgery which have to do with trauma, its immediate and distant effects and complications."

The problem which confronts us is often perplexing and appeals to the imagination, for trauma immediately affects any, or many, parts of the body. The most obvious lesion, a fracture for example, is often the least serious. Internal injuries, the symptoms of which may be for hours vague and confusing, and injuries to muscles, tendons, blood vessels and nerves demand keen judgment and dexterous skill in their diagnosis and treatment. Added to this we always have the great problem of shock in its various stages and burns caused by different agents and of varying degrees.

## WOUNDS

In the progress of the surgery of trauma, anesthesia, asepsis, antisepsis and control of hemorrhage have played important rôles but, as Reid[39] and Whipple[46,47] have pointed out, to these must be added another factor, just as important, a better knowledge of wound healing. This means recognition of the fundamental principles of the care of wounds: the avoidance of necrosis, of débris and, as much as possible, of the presence of foreign bodies in wounds. This essential knowledge was possessed by the immortal Paré, whom this association may well honor as one of the fathers of the surgery of trauma.

After trauma, when it becomes necessary to intervene surgically, the technic should, of course, be as atraumatic as possible. The greatest deference should be paid to viable tissues. The surgeon should avoid trauma to them in any way, should preserve always their maximal blood supply and should ever be on the alert to avoid dead spaces or the leaving of clots of blood. At the same time he never should constrict tissues by drawing ligatures too tightly and he should avoid ligatures that are too large or an overabundance of suture material.

Undoubtedly, two of the greatest lessons in wound healing learned during the first World War was the execution of proper débridement and the carrying out of the Carrel-Dakin technic. What I should like to emphasize today is that much of this knowledge is being lost and that many of our interns now leave the services of their hospitals without having been thoroughly trained in this technic. While antiseptics come and antiseptics go, I am of the opinion that Dakin's solution—(0.5 sodium hypochlorite in hypertonic saline solution)—still remains the most reliable one yet discovered. But like so many other good things in life, it is often discarded as having been unsatisfactory when the poor result was actually due to failure on the part of the person using it to familiarize himself thoroughly with the technic. Many advocate the use of azochloramide, a new complex chlorine compound which liberates small amounts of chlorine gradually over a long period in contrast with the rapid liberation of chlorine from Dakin's solution which requires frequent changes of dressings and precautions against irritation. However, he should realize that no antiseptic substance should ever take the place of a thorough cleansing of the open wound with soap and water when dirt and grease are present. This was emphasized by the French surgeons during the first World War who,

for lack of antiseptic substances were often limited to this one procedure and yet achieved satisfactory results. This, followed by copious washing with physiologic solution of sodium chloride, I have depended on for years rather than on the application of antiseptic preparations, because I am of the opinion that antiseptic substances often add insult to injury by inflaming the traumatized tissues by a chemical irritant.

Many wounds, superficial and considered trivial, prove to be fatal. We can all recall, only a few years ago, that the son of the late President Coolidge died as a result of a blister on his heel. This tragedy can be multiplied every year by the thousands. We have all seen the most serious complications follow a scratch or a puncture wound. I heartily agree with Royster[40,41] that the expression "minor surgery" should be deleted from our medical terminology because any wound is potentially serious and as he said: "The more 'minor' the surgeon, the more 'major' the operation will become before he is through with it."

Absolute rest to the traumatized part plays an important rôle in wound healing, and in the comfort of the patient as emphasized years ago by Hilton, Baron Larrey and Billroth. In fact, these basic and fundamental principles, laid down by the masters of surgery years ago, are as important today as then and to them we should be eternally grateful. As Bernard of Chartres said long ago, perhaps "we moderns are dwarfs standing upon the shoulders of giants."

## FRACTURES

When one attempts to review the progress which has been made in the treatment of fractures, he should remember that roentgen rays did not add a principle but only an aid in carrying out the fundamental concept and basic principles laid down by the great master surgeons of the past. Immediate reduction, so far as possible, and complete immobilization are essential. Progress has been made in treating various types of fractures by skeletal-fixation devices in plaster, thereby securing rigid immobilization. This is often better than the use of weights and pulleys. By the use of this method and infrequent dressings, as long emphasized by Winnett Orr,[37] Trueta[43] reported but six deaths in 1,073 cases of gunshot fracture. In his opinion this method "has given a new direction to surgery."

Metal fixation of fractures by vitallium, an alloy of chromium, cobalt and molybdenum, as brought out by Venable and Stuck[44] has been a definite step forward in the treatment of fractures. As this

metal is innocuous in the tissue fluids, and produces no electrolysis it, therefore, lends itself to a wide field of usefulness. But a word of caution should be sounded here and that is that this metal or any other ought never to supplant sound surgical judgment with regard to the question of open or closed reduction of fractures. The open operation and the invention of all kinds of gadgets should not lead us too far away from conservative and time-proven methods. We should remember always cardinal principles and also that often what is apparently new is old in basic principle.

The chief cause of preventable deaths in the first World War, as well as in the late war in Spain, was poorly treated fractures of the femur. The British mortality from this injury dropped from 50 per cent to 15 per cent when fixed emergency splinting was introduced.

The treatment of ununited fractures remains a problem today on which we are still looking for more knowledge. From the chemist we may expect more light regarding the regeneration of bone in our search for better methods of bone grafting for ununited fractures.

First aid and transportation of the injured is one of the most important factors in the care of fractures. Often careless handling of the injured person by attendants produces as much damage as, or more damage than, the original trauma. Many a person with a fracture of the spinal column or an extremity is made much worse by the unfortunate way in which he is handled soon after being injured. As surgeons, we are especially interested in the transportation of patients with fractures, and we are, therefore, enthusiastic supporters of first aid training for policemen, firemen, trainmen, ambulance attendants, Red Cross workers, boy scouts and the public generally. We should urge the use of fixed traction in all ambulances. Only by having patients' limbs, necks or spines properly splinted and immobilized can they secure the best chance of having their life saved, of securing the earliest reduction and of suffering the least economic loss.

### CHEMOTHERAPY

From all the reports to date, the surgeon undoubtedly has, in sulfanilamide, a most potent aid in the treatment of contaminated wounds and compound fractures; this aid has both a systemic and local protective effect. Aside from antitoxic serums, this is the first protective systemic agent we ever have had which assisted the patient to cope with infection from within. Robert W. Johnson, Jr.,[29,30] has reported the systemic effect of this drug in treatment of

sixty-seven patients, all suffering from major injuries with severely contaminated, compound fractures. Fifty healed without infection. No infection occurred in any case in which the prophylactic dosage was adequate.

The local application of this drug has been carried out by Jensen[26,27] and his associates at the University of Minnesota, who reported in 1939 that in thirty-nine cases of compound fracture not a single wound infection occurred. The treatment consisted of thorough débridement, careful hemostasis, introduction of 5 to 15 Gm. of crystalline sulfanilamide into the wound and primary closure without tension. Recently, in a letter, Jensen informed me that the total number of such patients treated has amounted to 101, with an incidence of infection of only 4 per cent. He wrote that "in wounds where extensive loss of soft tissue has occurred, resulting in a defect which cannot be closed by primary suture, careful débridement, followed by packing the wound with many grams of sulfanilamide and in turn sealing the powder in which vaselined gauze strips and then immobilizing the extremity in a plaster cast, will prevent primary wound infection.

"This drug is at present being used on an extensive scale by Dr. Leonard Colbrook[7] of England, co-author with Dr. Meare Kenny, of one of the first papers to appear in the English language on the use of sulfanilamide in compound fractures."

It appears at this time that we have sufficient evidence to assume that this drug is one of the surgeon's most valuable allies, but as Johnson[29] has emphasized: "Chemotherapy complements but does not replace in any way sound and necessary surgical procedure," consisting of thorough débridement, immediate reduction, complete immobilization and administration of serum. The question of sulfanilamide causing delay in wound healing has been intimated by Bricker and Graham[4] but the prevention of infection is of such major importance that in spite of possible disadvantages the use of this drug is valuable.

### ANESTHESIA

Any progress in this science is received by no surgeon more gratefully and eagerly than by the one interested directly in trauma for so often his patients are brought to him already in a weakened condition as the result of trauma, hemorrhage and shock. Because they are in dire need of an anesthetic which will reduce their waning vitality as little as possible, the choice of the anesthetic and the anesthetist

is of paramount importance. Every well equipped hospital should have, as far as possible, a professional physician anesthetist, who will evaluate each individual case and relieve the surgeon from all responsibility of the anesthesia.

### AMPUTATIONS

In trauma often a speedy appraisal of the situation and even quicker action is imperative. This is especially true as regards amputations. In the event we are drawn in this second World War many of us will be confronted with the problem of amputation. It would be well to familiarize ourselves with the pronouncements of Baron Dominique Jean Larrey,[33] surgeon-in-chief to the Grand Army of Napoleon, who is reputed to have performed 125 amputations in a day. In his Mémoires de Chirurgie Militaire, Paris, 1812, he wrote on the indications for primary and secondary amputations in battle casualties, and their evaluation in the light of his experience in the late war.

### BURNS

Of all wounds there are none which demand more urgent and immediate treatment than those caused by burns, no matter what their cause. In few emergencies is a surgeon called on to exercise more skill, judgment, care and energy than in the treatment of an extensive burn. His keenest efforts are concentrated in combating three serious dangers: shock, toxemia and infection. The mortality and the unsightly scarring following extensive burns have decreased considerably since tannic acid, silver nitrate and gentian violet treatment have changed this lesion into that approximating a clean surgical wound, as has been so well shown by Blackfield and Goldman.[2]

### MUSCLES AND TENDONS

Partial ruptures (tears) and complete ruptures of muscles and tendons and dislocations of tendons occur much more frequently than is usually supposed. As the writer has emphasized,[11–17] many cases go weeks, months or years incorrectly diagnozed. The presence of a large hematoma in an extremity should make one suspicious of a probable muscle tear and often one is able to see and feel a hiatus. If surgical repair is not done early, contracture and fibrosis often make later repair unsatisfactory; if done early, especially in extensive and complete tears, much time will be saved and a much better ultimate functional result will be obtained.

In lacerations, tests should always be made as emphasized by Bunnell[5] "before the anesthetic is started to determine whether or not the nerves and tendons are injured. . . . Primary repair of tendons should not be done except under strict indications covering the nature of the wound and adequate facilities of both hospital and surgeon. Operation must be prompt, debridement thorough and all vulnerable parts should be closed over. Repairing within a sheath is the most difficult. Trauma should be minimal and the tendon stitch simple and of non-irritating material, preferably stainless steel wire. This may be left in the tendon or be placed in such a way that the wire is removable."

### FACE

Much progress was made in the treatment of this type of injury in the first World War, but no less an authority than Blair[3] has written: "Today many are not receiving the most appropriate care. . . . Excepting trauma of vital organs and their essential coverings, the final outcome of no injury is so directly dependent upon early proper care as injury of the face."

### HEAD AND NERVE INJURIES

The treatment of head injuries has tended very definitely to conservatism. Surgery is carried out only when very definite and clear cut indications present themselves. Patients with subdural hematomas are today operated on frequently through small craniotomy openings instead of through large osteoplastic flaps and the results of such treatment has proved satisfactory in the relief of symptoms. All operations for acute head injuries should be done, as far as possible, under local anesthesia. The anesthetic solution should be injected some distance from the wound. After thorough débridement of the wound it should be closed in most cases without drainage. In general, supportive treatment directed toward complete rest and an adequate caloric and fluid intake are of immeasurable value. If infection is a probability, chemotherapeutic agents are used freely. It is not untimely to sound a word of warning against the promiscuous use of dehydration therapy, which has a very limited usefulness and may be harmful.

One of the outstanding advances in treatment of trauma of the nervous system has been the recognition and treatment of ruptured *intervertebral disks*. It has been found that this lesion usually presents a fairly definite clinical picture. The surgical attack on this recently

has been so simplified that now muscles need be retracted only on one side of the spinal column, no laminae need be completely removed nor any of the posterior processes disturbed. The results following this procedure, although it is too early to evaluate them accurately, certainly appear to be satisfactory.

In injury to the peripheral nerves a detailed and painstaking examination is of paramount importance. It is sad when one sees today, weeks or months after injury, patients who have had peripheral nerves improperly repaired or even sutured to the severed end of tendons. Such cases are seldom reported but are seen not infrequently. All of this only emphasizes the importance of having patients, who have suffered such trauma, seen by the most competent surgeons.

### POST-TRAUMATIC PAINFUL OSTEOPOROSIS

This condition, because of the work of Sudeck,[42] Gurd[20] and Hermann,[24] is being more frequently recognized than before and has reacted favorably to interruption of the sympathetic nerve supply to the affected region, thus saving the afflicted many months of suffering and disability.

### THORAX

The surgery of the chest has always possessed a fascination and charm for the adventurous surgeon, involving as it does that of the heart and lungs, the most obviously vital organs in the body. An operation on these moving structures will never fail to thrill the most indifferent and cold-blooded surgeon (Hegner).[22]

Before the first World War the high mortality resulting from intervention for conditions which were then considered to be sufficiently serious to justify operative treatment impressed surgeons with the idea that operations on the chest were excessively dangerous. Having served in three European Wars, it was my privilege to have seen an enormous number of chest wounds of all descriptions with an abundant opportunity to observe both their immediate effects and the more remote ones, such as those produced by infection.

One of the most striking observations was in regard to wounds opening the pleural cavity—the so-called sucking wounds. It was noticed that with such a wound a man might do fairly well for a short time and then rapidly go into shock and die. The reason was, if we understand the phenomena of shock, a displacement and flapping of

the mediastinum and a lack of oxidation due to inadequacy of respiration. If the admission of air through the wound were stopped, these patients did as well as those with none-sucking wounds. It became the rule, therefore, to close such wounds as soon as possible, even if they were only provisionally sewn together and had to be operated upon and reclosed later. It was found that if shock and flapping of the mediastinum could thus be prevented the patient could subsequently withstand a formal operation in the course of which the wound of the chest wall could be excised and enlarged, the lungs withdrawn if necessary, the wounds in the latter also excised and sutured and the chest finally closed. Closure of the chest, if only for a day or two to enable the final functions to become more readjusted, was found to be imperative. Naturally, under these conditions it was of extreme importance that infection should be prevented and it was therefore necessary methodically to remove foreign bodies, torn and devitalized tissue, and more particularly, fragments of ribs, which were found frequently to provoke infection. It was seen that extensive exposure and handling of the lungs was possible, and our pre-war ideas as to the dangers of thoracic surgery became greatly modified. Much also was learned in regard to the treatment of infection of the pleural cavities, including the empyemas caused by pneumonia as well as those due to wounds.

Roentgenology still remains a chief aid in arriving at the exact diagnosis and extent of intrathoracic trauma. There are, however, a few cases in which a single roentgenogram is not as helpful as the physical findings. For example, there are some cases of localized pneumothorax in which the roentgenogram does not reveal sufficient information that a precise diagnosis can be made but the physical findings will be conclusive. This only emphasizes that we should never get very far away from our basic principles of diagnosis. Among the physical findings, the importance of inspection and palpation cannot be overemphasized. The surgeon today, treating a thoracic injury, should not forget what his predecessors knew and used to good advantage, that is, that to depend solely on the newer and ultrascientific methods is not wise. As always, evaluation of all the factors is essential.

*Hemothorax and Pneumothorax.* If the fluid or gas is small in amount and is causing no particular symptoms, this condition can be treated conservatively by rest in bed. Removal of air or blood is indicated when there is a sufficient quantity to embarrass the circulation and respiration. Exploratory thoracic operations are only

rarely indicated, and this indication exists when the tear in the lung remains open and the condition does not yield to conservative measures.

In all trauma to the thorax one must try to visualize the condition of the intrathoracic structures prior to the injury in order not to be mislead by abnormal conditions which may not be associated in any way with the trauma. In no injuries of the human body can meddlesome attempts to intervene more greatly jeopardize the patient's chance of recovery than in injuries of the thorax; every movement of the patient adds insult to injury. Briefly, the trend in treatment of thoracic injuries can be epitomized in the word "conservatism."

*Heart.* In traumatic lesions of the thorax in general, frequent examination of the heart must be made in order to observe any change in its size or position. It should be remembered that the heart can be seriously traumatized by a nonpenetrating injury to the thorax. Such direct violence occurs more frequently than in the past and is often due to compression of the thorax against automobile steering-wheels. Therefore, traumatic myocarditis is no longer considered a myth. Beck[1] believes that "the heart is the recipient of many injuries" and that most of them "are not recognized." Here again, one must attempt to form some idea of the integrity of this organ prior to the injury, and any progressive changes that may thereafter appear. The immediate prognosis in the presence of wounds of the heart depends chiefly on the interval between injury and operation as shown by Elkin[9] in a review of twenty-two stab wounds.

## ESOPHAGUS

External injury to this organ is so rare that it does not warrant discussion in this review.

## ARTERIES AND VEINS

If an acute injury of a main artery to an extremity necessitates ligation, ligation of the accompanying vein should be considered. A useful but not absolute test in determining whether or not the main vein should be ligated is that advised separately by Henle[23] and Coenen.[6] This test relies on a retrograde "flow of blood from the open end of the distal arterial segment, the proximal portion being compressed, as an indication of satisfactory collateral circulation." If the sign is positive, ligation of the accompanying vein is contra-

indicated; and when this sign is negative, ligation of the main venous channel is advocated.[38]

### ABDOMEN

Abdominal injuries, whether caused by penetrating wounds or a contusion of the abdomen with resulting visceral damage, are accompanied by a mortality rate of 50 per cent.[31] The mortality depends (1) on the type of injury, (2) on the time elapsing before operation, and (3) on the structures involved. In order to reduce this mortality we must emphasize more and more the importance of having these patients transferred immediately to a hospital where they can be thoroughly examined and observed constantly. After they have recovered from their initial shock it is often more prudent, in case of doubt as to visceral perforation, to perform an exploratory laparotomy rather than to delay too long.

*Gastrointestinal Tract.* Of the hollow viscera the small intestines are the most frequently injured, the large intestine next and the stomach least frequently. Rigidity of the abdominal wall, which is first localized and soon begins to spread, is always present. "When to operate" as G. G. Davis writes[8] is the all important question in internal injuries of nonpenetrating force. It is generally recognized that in this type of injury operation should be preceded by the treatment for shock. The demonstration of gas in the free abdominal cavity is a definite sign of perforation and calls for immediate operation.

Often when the abdomen has been opened the proper surgical therapy tries the ingenuity of the most experienced and versatile surgeon. In a word, the intervention should be brief. That procedure which will close all perforations most quickly and with the least amount of shock, is the one which should be selected. One must decide in a few moments the question of exteriorization, of resection or of enterostomy.

*Traumatic Appendicitis.* The incidence of this condition is not so important as is the fact that the disease exists as a clinical entity. It is a subject in which employers of labor and accident insurance companies are deeply interested.[35]

*Liver.* The liver is injured more often than any other internal organ because of its composition. Gunshot wounds comprise about 60 per cent of the wounds to the liver. The others are caused by falls, automobile accidents and stabs. Graham[18] writes that "the diagnosis of liver lesions is often not possible until the next day. If it cannot be

based upon abnormal dullness then we must depend upon the disappearance of liver dullness produced by gradually developing tympanitis caused by hematomas or injuries interrupting the nerve impulses at the base of the mesentery."

Krieg[32] has reviewed sixty cases in most of which the patients were seen soon after the accident and in which the total mortality was 61.6 per cent and the postoperative mortality 56.6 per cent. Shock from trauma was found to be the most common fatal complication. Superficial wounds may be approximated by suture but deep wounds should be treated by small drains inserted deeply. Krieg expressed the opinion that abdominal drainage should be instituted in all cases.

Graham[18] says "suture is the ideal method; packing for an emergency. The greatest skill is haemostasis; the greatest error, hasty examination; the greatest virtue, speed."

Green[19] believes that glycosuria probably occurs frequently following liver injuries.

Injuries to the gallbladder or bile ducts are not encountered frequently but when present demand immediate surgical intervention. According to LeRoy Long[34] "the history of a crushing injury of the right upper abdomen, followed in a few days by a slight jaundice, bile in the urine, absence of bile in the feces, and later, usually a week or ten days, a distoned abdomen, flat on percussion, practically establishes the diagnosis of rupture of some part of the biliary tract." Paracentesis may cinch the diagnosis.

*Spleen.* Injuries to the spleen occur about half as frequently as injuries to the liver. As Foster[10] has shown in an analysis of twenty cases in which operation was performed, diagnosis is not made as frequently and as early as it should be. He emphasized localized abdominal rigidity and shifting dullness as the two important diagnostic signs; preoperative transfusion and autotransfusion as life saving procedures; splenectomy as the treatment of choice. Webb[45] has found elevation of the diaphragm on the left side, as well as cloudiness in the region of the spleen and displacement of the stomach towards the right, as revealed roentgenologically, to be helpful. Delayed intra-abdominal bleeding (ten days) from a fractured spleen has been reported by Jones.[31]

*Pancreas.* Isolated injuries of this organ are rare. A complete laceration of the organ may liberate the pancreatic secretions with resulting pancreatic digestion and necrosis following. Unless repair with drainage is established death usually ensues.

The postoperative care is essentially that of acute peritonitis. Morphine in adequate doses, abdominal decompression by the Wangensteen method and the preservation of a fluid balance can not be overemphasized.

*Peritonism or traumatic peritonitis*, called by some "sympathetic or abdominal shock," must be kept in mind as it may be caused by the presence of a fractured vertebra. The clinical picture is one known as a "knock-out," so severe is the shock. There is intense pain, nausea and vomiting, board-like rigidity of abdomen, diffuse tenderness and absence of peristaltic sounds, rapid pulse and low blood pressure. A laparotomy would seem imperative but traumatic peritonitis readily subsides and disappears under primary treatment for shock (Hertz and Stalker).[25]

### UROLOGICAL TRACT

*Kidney.* This organ, because of its well protected position, is not often injured. When trauma does occur, however, it is frequently serious because of the important secretory function and rich vascularity of the kidney. A contusion or rupture of this organ may be a complication of fracture of the vertebrae or bony pelvis. Hematuria, following injury, should always make one suspect renal trauma and then, by repeated physical and urinary examinations, measurement of the fluid exchange, examination of the blood, roentgenographic examination and pyelography, one should be able to arrive at an accurate diagnosis. The absence of hematuria, however, when other signs of renal trauma exist, is suggestive of complete laceration or occlusion of the ureter.

Conservative treatment usually is indicated in cases of renal trauma. According to Harrison,[21] who recently analyzed twenty-seven such cases, "There is a tendency for spontaneous improvement owing to the processes of natural repair. The absolute indications for operation are persistent hemorrhage, urinary extravasation, or renal infection."

*Bladder.* Early recognition is imperative as the mortality rises terrifically after the first few hours following injury. Johnson[28] stated "that after 24 hours the mortality jumps from about 10 per cent to 40 per cent or even 50 per cent." Only by early recognition and immediate operation can this be reduced. When on physical examination the findings are inconclusive, early diagnosis can be made most accurately by proper application of the cystogram.

*Urethra.* When this lesion occurs, immediate end-to-end anastomosis should be performed. A retention catheter should not be inserted but the urine diverted by suprapubic cystostomy. This procedure is to prevent the formation of intractable stricture.

### PSYCHIC TRAUMA

At present the great mass of the injured are treated in general hospitals. The patient is seen by the visiting surgeon but often the treatment is entrusted to a less experienced man. Frequently the attending surgeon is one who has little interest in, and who has given little time to, the surgery of trauma and to the great development made in it during the past few years; he may care nothing at all about industrial relations. The injured, who is entitled to the best scientific treatment of the day, not infrequently finds that he is not in the most skilled hands and that, as an industrial case, he is regarded in the hospital as a nuisance. Even if he is fortunate enough to fall into skilled hands, and the immediate treatment or operation is performed properly and well, what often follows? For weeks, and not infrequently for months, the patient is left often to his own devices. Lying there in idleness, with worry and melancholy his chief companions, is it any wonder that traumatic neurosis develops? Satisfied with a good surgical end result, very little thought is given to the injured patient's future economic usefulness. We should remember, therefore, that detrimental psychic reactions usually accompany deformities following injuries. The surgeon must not lose himself in the problem of the repair of the physical trauma and overlook or neglect the psychic trauma, with the result that "the most perfect restoration may be utterly unappreciated."[3] The treatment of both should go hand in hand or the surgeon has not measured up to his full obligation. We should always remember that we are not just artisans or technicians but physicians and philosophers in the broadest meaning of the words.

The services of many of our large hospitals and teaching institutions should be reorganized in order to treat more effectively injured patients. Today there is often confusion because of the unscientific and entirely unwarranted methods of assorting traumatic patients among various specialists according to the organs affected. For example, a patient with an injury to his chest and a fracture of the femoral neck is assigned to a thoracic surgeon with the result that the femoral fracture receives only scant attention; a patient with a severe head injury is assigned to an orthopedic surgeon because of an

associated fracture of a long bone; a patient with an acute fracture is referred to an abdominal surgeon, while one with an ununited fracture is referred to an orthopedic surgeon. We have all known of cases of conspicuous fracture and associated rupture of the bladder or other viscus, in which the latter would be undiagnosed for hours because the patient was referred to the fracture service. Again, a patient may be injured in an industry and be classified as an industrial case. This is absurd. Trauma, whether received in the factory, at home, or on the highway does not differ and the same fundamental principles of surgery apply.

### TREND TOWARDS SPECIALISM

It is to be expected that the trend today in everything is towards specialism and this is certainly true in the rapidly expanding field of general surgery; but this can be carried too far. If we visualize the future we can be sure that this world will continue to become more mechanized and to accelerate its speed and the result of this will be an increase in trauma. To recognize immediately the broad problem presented, to treat adequately the seriously injured, we should have surgeons with as extensive a general experience as is possible to attain. Only by so doing can we expect to cope with the surgical exigencies of this rapidly changing world. To do this efficiently, our medical schools will have to give more time to the teaching of this important subject. I realize that the curriculum is already overcrowded, but, like many other decisions in life, the less essential must give way to the more essential. Recent graduates will have to treat many more patients with trauma than they will patients suffering from brain tumor, goiter or bronchiogenic carcinoma.

Our association should develop and promulgate fundamental principles in the care and treatment of the injured. This information should be made available to the physicians working in the smaller institutions throughout the country to enable them to treat more efficiently their patients with acute trauma. We should strive to get the co-operation of administrative staffs of hospitals, large and small, to recognize the importance of being equipped at a moment's notice to care adequately for the seriously injured. They should realize that the first hour of injury is the most important one.

We have, therefore, a great opportunity to improve and standardize the methods of the surgery of trauma, affecting the small hospitals in the rural districts as well as the large ones in the great metropolitan centers. That the Fellows will meet this opportunity I

entertain not the slightest doubt. If we succeed in this, the medical profession and hospitals in America will be prepared at any time to be of vast help to the Army and Navy in time of war. Anything that we can do to stimulate the education of the lay public in the care of highway accidents should be done. The American Red Cross has established almost 3,000 Emergency First Aid Stations along our highways. It has, through its Chapters, certificated approximately over two million persons as having completed courses in first aid under regularly qualified instructors.

I ardently wish that it had been in my power to weave together more completely the fruitful contributions that have come from many of you which have played such an important part in the progress of the surgery of trauma. I fully realize how incomplete this review has been but I hope, nevertheless, that it is apparent that much important work is to be done. If done, a movement will be set in motion which will prove a vast fund of permanent value not only to our present generation but to generations to come.

As one of the founders of the American Association for the Surgery of Trauma I am justly proud of the success it has already achieved but I should like to see it become more than a surgical society, more than a scientific body; I should like to see it become a great and potent influence in shaping and moulding the careers of the younger generation of American surgeons and of saving more lives all over this continent. If any of you, however, think this is but a dream, then I say to you, let us cherish it just the same and hope it will come true. That dreams may accomplish much, I need only close with this story.

According to the literature of ancient Ireland there was a great musician by the name of Dagda who played a harp which had only three strings, but from which he produced the most marvelous music. It was said that when he struck the first string, the music made the women weep because it was the immemorial music of woe, and when he struck the second string, the music made the young men laugh because it was the immemorial music of mirth, but when he caressed the third string, the music brought consoling understanding and soothing peace and gladness to all because it was the immemorial music of dreams.

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# Original Articles

## THE TREATMENT OF FRESH WOUNDS

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A WOUND is a break in the continuity of tissue. Usually we think of it as a break through the skin only. In reality a wound of the deeper structures is more important than that of the integument.

The type in which we are interested in this discourse is that which comes from trauma. These are divided into three classes: (1) those caused by impact from without, (2) those caused by rupture from within, and (3) those produced by burns. Among the contact wounds are abrasions, contusions, punctures, incisions and lacerations. The insults to the tissue vary from slight, superficial abrasions with destruction of the outer covering of the skin to the more severe and destructive injuries of the muscle tendons, nerves, blood vessels, bones and viscera. Slight abrasions if infected may become a problem as serious as the more extensive lacerations. The former are usually neglected; the latter are always treated. The wounds caused by rupture from within are exemplified by the compound fracture in which bone structure is forced through the skin. These openings may be very small, often only a blister or even a microscopic opening. They may be quite large where spicules of bone protrude through the skin from within. Wounds caused by burns are due to actual flame, contact with hot objects, electrical currents and chemicals.

The treatment of all of these wounds is as varied as the degree and extent of the injury, the structures involved and the causative factors.

All *treatment methods* must be efficient, practical, simple and economical. Treatment must have as its object (1) hemostasis, (2) treatment of shock, (3) tissue immobilization and relief of pain, (4) prevention of infection, (5) eradication of infection if such exists, (6) promotion of healing, (7) re-establishment of function with the least possible morbidity and disablement, and (8) reduction of the

economic loss to employer and employee. These are enumerated in their order of emergency.

*Hemostasis* is easily accomplished except in the punctured and lacerated wounds and compound fractures. It should be brought about early with the utmost speed and accuracy. Mass ligation should not be done. Ecchymosis, a hemorrhage into the skin, is of little consequence, but hematomas, especially when large and of the dissecting variety along the tendon and muscle sheaths and bone, may produce a definite problem. Large collections of blood should be evacuated and the source of the bleeding stopped. Elevation of the extremity should always be done since it lessens the blood to the part.

*Shock* resulting from exposure, extensive hemorrhage and trauma to viscera, nerve trunks and nerve centers as well as from extensive bone and muscle injury must be combatted early by the well known methods, namely, morphine to promote rest, fluids to supply the blood lost, blood transfusions and blood plasma.

*Tissue immobilization* relieves pain, hastens the repair of injured tissues and is easily brought about by strapping, suturing and splinting. In all tendon and nerve injuries and all larger wounds and especially those involving bones and joints, this is of the greatest importance.

*Prevention and eradication of infection and aids for promotion of healing* will be considered under one heading. Precisely what is your procedure of wound treatment? As I stated above, any treatment method should be efficient, practical, simple and economical.

In the same manner that many have sought a short road to success so we have too often attempted to find a "short cut" to wound healing. It seems to me that we spend too much of our time going about looking for "false gods." We have too often been unwilling to put forth the necessary units of energy to gain our best results. If one can bring about wound healing by the laying on of hands, by the oral administration of drugs, by pouring medicaments into a wound, why wash and scrub and work? If we can benumb our conscience and satisfy our patients by showering into the wound quantities of highly colored and often brilliantly hued medicaments, why not? The objection is that most wounds cannot be healed that way.

For many years an ideal antiseptic has been sought. Many have been brought forth, some of value, others without value, some entirely useless, others even harmful. Some are innocuous; others destroy a few of the organisms but also some of the good tissue. We

all recognize some of our former "allies" when I speak of iodine, mercurochrome, mercresin, merthiolate, the various chloramines and chloramides, triacetin, gentian violet, picric acid, zinc peroxide, etc., etc. I do not wish to be understood as saying that under certain circumstances some of these may not have value. Iodine still has its place in the preparation of skin, and zinc peroxide, as brought out by Meleney,[1] seems to give that author some satisfactory results. However, I believe that none of the preparations mentioned is an ideal antiseptic for universal treatment of traumatic wounds.

It seems to me that we have lost the trail blazed for us a quarter of a century ago when Carrel and Dakin in December, 1914, began their monumental work at the French Military Hospital No. 21, at Compiegne.

During the World War the Carrel-Dakin method was used very extensively. It was acknowledged by many as the most outstanding method of wound treatment since Lister. Results hitherto unequaled were reported. The literature contained numerous and outstanding articles in the medical journals abroad and in this country. Notably among these were papers by William O'Neill Sherman[2,3] and Frank D. Smythe.[4]

The Rockefeller Institute for Medical Research, beginning in 1917, gave a thorough course of instruction in the treatment of wounds by Carrel's method. In subsequent years numerous modifications were suggested by Carrel and others, but none seem to have stood the test of time.

Over all these years Sherman has never discontinued the use of the Carrel method of wound preparation and the use of sodium hypochlorite solution and has reported their use in a large series of cases.

Among others who successfully continued the use of Dakin solutions were Kanavel and Koch,[5] Young[6] and Rhodes.[7]

Another noteworthy contribution came to me recently from Dr. E. P. Sullivan, a noted veterinarian in Saratoga Springs, New York, who has used sodium hypochlorite solution in his practice on thoroughbred cattle and race horses over a period of many years. I quote:

"A physician returning from the World War in 1918, told me the wonderful success they had with treating wounds with Dakin's Solution. Before that time I used mostly the coal tar products, iodine, etc., and if you use any of them strong enough to destroy microscopic organisms they will irritate the tissues. I prepare the tissues as recommended by Carrel. If I can get to a wound before infection

sets in I get healing by first intention, and if the wound is infected by keeping wet packs on it of a one percent solution it will destroy in a very short time any organisms that have invaded the tissues. I have never found any case where I have used it where I have not received excellent results. I have never used it in the eye, but in any throat infection I have I keep syringing the mouth out every two hours with a one percent solution and get wonderful results. I use it for a mouth wash for myself night and morning. It will destroy streptococci, the causative factor in septic sore throat. There are many kinds of chlorine preparations on the market, but I find sodium hypochlorite has more available chlorine and is given off quicker than any of the other solutions. It will destroy mostly all organisms. A few of the exceptions are tuberculous and anthrax. There might be a number of others. I make it up fresh as I get better results this way. It is the most marvelous antiseptic that has ever come into my hands in thirty-four years of practice as a veterinarian. Would consider it an honor to have you quote me in your paper."

A further review shows that many authors mention the use of the Carrel-Dakin method but state that the sodium hypochlorite solution is not practical because of its instability and because of the time and labor required in the preparation of the solution. For a number of years now a concentrated solution, which has as its active ingredient sodium hypochlorite, has been available in a product known as "hychlorite." From this a stable and entirely efficient solution may be made by adding one part of hychlorite to seven parts of sterile saline solution or sterile distilled water. This gives a solution of sodium hypochlorite of approximately .45 to .5, which is the ideal strength. Any higher concentration would irritate the skin and lower concentrations would not as rapidly destroy the organisms nor dissolve the necrotic tissue in which they lie. Titration of this solution is not necessary. It is quite stable since it retains its strength for a week or ten days. It is essentially nonirritating, noncaustic and nontoxic and has a high bactericidal and solvent power. Thus the objections so frequently mentioned no longer exist.

The treatment of wounds according to the Carrel method is divided into two very distinct parts: (1) the thorough preparation and débridement of the wound and (2) the application of the sodium hypochlorite solution.

If I go into detail which seems unnecessary, let it be for those who read, not necessarily for those who listen. We all agree that the most important part of wound treatment and the prevention of infection

is the thorough preparation of the wound itself. *This cannot be overemphasized.* The cleansing and débridement must be done with surgical precision and scrupulous asepsis. As a standard procedure, the wound, large or small, is first covered with sterile gauze which is saturated in a .5 sodium hypochlorite solution. The surrounding surface is then washed and scrubbed thoroughly and repeatedly with liquid soap and sterile water, care being taken not to wash infection from the skin into the wound. After this has been thoroughly accomplished, the shaving of the skin far and wide of the incision is done. Again the skin is thoroughly cleansed of grease and other inabsorbable material by the use of soap and water followed by ether. This done, the wound itself receives our attention.

In the more extensive cases an intravenous anesthetic may be used or the tissues may be infiltrated with 1 per cent novocaine injected around the edges of the wound. The wound is thoroughly washed with copious quantities of soap and water and flushed with sodium hypochlorite solution. All corners of the wound are examined, bleeding surfaces are ligated and loose tags of tissue such as skin, fat or fascia, or loose pieces of detached bone or foreign material are carefully removed. It is necessary that all tissue hopelessly bruised or impregnated with dirt should be eradicated. Wound edges should be dissected until a healthy bleeding surface is obtained. The wound is flushed with sodium hypochlorite solution. It is not always possible to tell from the primary examination which of the tissues are completely devitalized, therefore, a secondary débridement on the second, third and fourth days is occasionally necessary. This is very important since the antiseptic solution destroys only those organisms with which it can come in contact and does not necessarily destroy those which lie in necrotic tissue or under the surface of granulation masses. It is also very important that the skin around the wound be thoroughly cleansed at each dressing.

The wound is now ready for the application of .5 per cent sodium hypochlorite solution in the form of moist dressings or, as is the case in the larger, deeper and more irregular wounds, the introduction of the well known Carrel tubes. Because the solution in antiseptic for a limited time, it is necessary to flush with a sufficient amount of Dakin's solution every two hours. When Dakinization is contemplated for more than several days, it is well to protect the skin around the edges with vaseline gauze since one cannot tell which skin is going to become irritated by the constant contact of this solution. These irrigations are continued until the wound is beginning to heal

and is free of all signs of infection. In superficial wounds, abrasions or minor bursting lacerations the application of the sodium hypochlorite is necessary for one or two days only.

We make every effort to see our patients within the first six hours after injury. Most of them are seen within the first hour. Too much importance cannot be placed upon the fact that early healing is imperative if we wish to prevent scars and secondary infection as well as excessive lost time on the part of the workman. Primary healing is our first aim and is easily accomplished when one deals with a fresh wound in its early stages. The greatest enemy of primary healing is infection. We realize, of course, that all wounds are contaminated. Not all wounds are infected. In fact, infection comes secondary to contamination. Experience has shown that it takes from three to five times as long to heal an infected wound as one which is merely contaminated.

When once a wound has become infected, débridement of necrotic tissue and thorough drainage plus repeated sterilization of the surrounding skin and the introduction of sodium hypochlorite solution by way of Carrel tubes into all the recesses of the wound is imperative. In 1930, Kanavel and Koch[5] wrote: "Infection will continue unabated as long as there is necrotic tissue present in the wound. Tissue which is obviously necrotic can safely be cut away. If no definite line of demarcation is present, 'chemical debridement' is safer than excision. We know of nothing more effective for this purpose than Dakin's solution. As was pointed out many years ago, Dakin's Solution properly prepared has the power of dissolving necrotic tissue without injuring the living tissue. It has, therefore, a very definite place in the treatment of suppurating wounds with profuse wound discharge and dead tissue in the floor of the wound. To obtain the best results it must be used in accordance with the technic outlined by Carrel and Dakin, i.e., the solution must contain .45 to .50 per cent sodium hypochlorite, it must not be excessively alkaline and it must be applied over the entire wound every two hours.

"As soon as the necrotic tissue has separated the wound very rapidly takes on a healthier appearance. Red granulation tissue begins to appear in the floor of the wound and the wound secretion is perceptibly diminished."

Much has been said in the literature concerning primary and secondary closure of wounds, but surgical judgment and experience must guide the surgeon in his decision as to when the wound should be closed.

In all compound wounds, even though pinpoint, as well as puncture wounds of all types, the underlying structures must be exposed by free and open incision so that the underlying structures as well as the bones may be thoroughly examined. In compound fractures we have two objects in view: (1) prevention of infection and (2) realignment and healing of the bone fragments. In my opinion there is no contraindication to applying some type of internal fixation if it is necessary to hold the bones in place. The internal fixation can very readily be removed after it once has been shown that the fragments will not dislocate. Infection can be prevented by repeated débridement and by continuous application of the sodium hypochlorite solution until the structures around the bone have been completely healed. Osteomyelitis should not occur if the patient is under our care from the beginning.

Compound wounds into the abdomen and chest cavity tax the surgical judgment to the utmost. Early interference may occasionally give disastrous results. However, I believe that one should attack these cases with radical surgery if there is any doubt as to the damage done in the cavity. Delay in these cases may spell disaster, and I believe that one had better operate too often than not often enough. Opening the abdomen and inspecting its contents will do little harm and may save the patient from a long continued peritonitis if not ultimate death.

In all early wounds, especially those seen within six hours, tendon suture as well as nerve suture is indicated. If there is soiling of tissues or not, sodium hypochlorite solution is applied and the wound is closed or left open a sufficiently long period of time to insure freedom from subsequent infection.

When the open wound is due to a burn, the necessary débridement is done at once. The wound is cleansed with sodium hypochlorite solution .25 to .50 per cent following which the paraffin wax is used. The wax dressing is applied as often as necessary, i.e., daily or on alternate days, depending upon the degree of the burn and the amount of wound secretion there is present. In the more severe burns repeated débridement of necrotic tissue is done as the case demands, each time spraying the paraffin cover over the entire burned area. Wounds treated in this way have healed with amazing rapidity and with a minimum of scar formation and contractures.

There are certain *aids in the promotion of healing* which should be mentioned, especially as concerns the subacute and chronic wounds. In the last fifteen years the use of vaccines, bacteriophage and

bacteriophage enzyme has been frequently cited in the American literature. Much has also been said of toxoids, toxins and antitoxins. Much has been written on the use of prontylin and neoprontosil, on sulfanilamide and sulfapyridin and more recently on sulfamethylthiazol for staphylococcic infection. The last named has now been withdrawn even for experimental purposes. In the discussion of these chemical agents in the prevention and treatment of infections resulting from industrial wounds, one must conclude that at best they are only aids and must not be substituted for the recognized methods of treatment. There is yet no "short cut" to wound healing. The treatment of wounds with the *x*-ray in the hands of some has brought about a promotion of healing, and I can readily see that in some of the deeper wounds it might have some value.

In those patients in whom there has been a considerable amount of shock and a prolonged loss of body fluids complicated by subacute or chronic infection, a high grade of anemia may readily develop. In these the various medicaments which have been described in the literature are of value. In my experience there is nothing which will give such spectacular and rapid results as maintenance of fluid balance and repeated transfusions of blood. We should be very familiar with the excellent work of Scudder and Drew[8] with reference to controlled fluid therapy.

The treatment of existing dyscrasia is so pertinent that it need only be mentioned.

*Re-establishment of function* with the least possible morbidity and disablement is highly important. When once the tissues have healed sufficiently, physical therapy, including hydro- and electrotherapy must be begun. This applies especially in the deeper wounds, after fractures and joint injuries. Nothing is more hopeless than an extremity in which the muscles, tendon sheaths and skin though healed are all massed together by adhesions, frequently produced by prolonged immobilization in plaster casts and splints. Early active and passive motion, massage, the whirlpool bath, short wave diathermy and muscle re-education and stimulation with the Morton Smart apparatus, all are valuable aids in the re-establishment of muscles, tendon, nerve and joint function. It is my opinion that the Physiotherapy Department is one of the most important departments in the hospital where traumatic wounds are treated. There is probably no other method of treatment in which there is so much "hocus pocus," so much of heat and light treatment which is entirely useless. There is too much of infra-violet and ultra-red, and I confuse

these terms advisedly. I am reminded of the man who had twenty-eight light treatments in twenty-seven days. Rehabilitation of structures calls for the rational application of physical therapeutic agents guided by cortical cells.

The patient himself can aid materially and should be encouraged in the normal use of his extremity at the earliest possible moment and continue to do so every day. A wound is not really healed until rehabilitation of injured tissues is complete. It is only by the applica-

TABLE I

CLASSIFICATION OF 20,557 OPEN WOUNDS (G)

Years 1938–1939

| | |
|---|---|
| Abrasions | 4,485 |
| Burns 1° and 2° | 2,214 |
| Burns 3° | 131 |
| Burns of eye | 178 |
| Lacerated wounds | 8,441 |
| Incised wounds | 3,047 |
| Puncture wounds | 1,409 |
| Infected wounds (seen 6 hours to days later) | 340 |
| Infected wounds (seen within 6 hours) | 2 |
| Fractures, compound | 265 |
| Amputations | 45 |

TABLE II

CLASSIFICATION OF 5,732 OPEN WOUNDS (S)

Years 1938–1939

| | |
|---|---|
| Abrasions | 1,399 |
| Burns 1° and 2° | 1,156 |
| Burns 3° | 2 |
| Burns of eye | 14 |
| Lacerated wounds | 2,560 |
| Puncture wounds | 376 |
| Infected wounds (seen 6 hours to days later) | 142 |
| Infected wounds (seen within 6 hours) | 1 |
| Fractures, compound | 74 |
| Amputations | 8 |

tion of all surgical, medical and physiotherapeutic principles that our best results can be obtained and that there can be a greater reduction of the economic loss to the employer and employee.

The treatment of wounds has for its object complete wound healing with the least amount of morbidity or disablement. We must at the earliest possible moment make a producer of him who might otherwise be a burden to society.

At one time or another we have tried most of the treatment methods. We have gone through all the phases from the oatmeal poultice to maggots, from the primary closure of all wounds to the

well known vaseline pack. We have watched the pendulum of treatment swing back and forth only to go back to the trail blazed for us a quarter of a century ago by Carrell.

TABLE III
COMPARATIVE STATISTICS OF 1936 AND 1939

| Abrasions (Not into Deep Structures) | Year 1936 When Iodine, Mercurochrome, Metaphen or Alcohol Was Used | Year 1939 When Carrel-Dakin Solution Was Used |
|---|---|---|
| Total cases | 899.0 | 760.0 |
| Total dressings | 3200.0 | 2010.0 |
| Days required for healing | 5854.0 | 2764.0 |
| Average days required for healing | 6.51 | 3.63 |
| Infected cases (first attention) | 4.0 | None |
| Days required for healing infected cases | 87.0 | None |
| Average days required for healing infected wounds | 21.75 | None |
| Per cent of infected wounds | 0.4 | None |

TABLE IV
COMPARATIVE STATISTICS OF 1936 AND 1939

| "Through Skin" Lesions (Including Lacerated, Contused, Incised, Compound Wounds and Compound Fractures) | Year 1936 When Iodine, Mercurochrome, Metaphen or Alcohol Was Used | Year 1939 When Carrel-Dakin Solution Was Used |
|---|---|---|
| Total cases | 805.0 | 700.0 |
| Total dressings | 6199.0 | 3971.0 |
| Days required for healing | 13,219.0 | 7589.0 |
| Average days required for healing | 16.42 | 10.84 |
| Infected cases (first attention) | 51.0 | 1.0 |
| Days required for healing infected cases | 2040.0 | 11.0 |
| Average days required for healing infected wounds | 40.0 | 11.0 |
| Per cent of infected wounds | 6.3 | 0.00014 |

Tables I, II, III and IV present tabulation of our results with a large number of cases. One will note with satisfaction that very many are of the minor injury class in which there is no time loss and no subsequent morbidity.

## CONCLUSIONS

The results obtained in treatment of 26,289 open wounds with only three infections in those cases seen within the first six hours speak for themselves. This is entirely due to the careful painstaking preparation of the wound, maintenance of asepsis and the application of sodium hypochlorite solution.

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# THE USE OF B.I.P.P. AND LIQUID PARAFFIN IN THE TREATMENT OF WOUNDS*

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THE B.I.P.P. treatment of wounds has been heard of by the majority of surgeons. It has been used by many but the real principles underlying its use have apparently been understood by comparatively few. The majority of those who have mastered this technic state most emphatically that without it, the surgery of trauma and of infected cases in general would be at best a much more difficult matter. We believe that continuous experience in the use of such a method for a period of more than twenty-three years should qualify us at least for an expression of opinion as to its value and safety. We believe that practically all objections to this method have arisen either from a lack of knowledge of the primary principles involved or from a faulty application of those principles.

B.I.P.P. was originally used by Mr. Rutherford Morison during the war of 1914 to 1918. Mr. Morison was at that time Professor of Surgery at Durham University. Like many other very good things, it was immediately misused to an extent that was positively alarming. One of us (L. H. McK.) well remembers those early days. I can still picture certain cases admitted to my ward in the Base Hospital. Knee joints were packed with as many ounces of B.I.P.P. as they would hold. I remember one chest wound with excision and tight closure, with more than six ounces of B.I.P.P. lying free in the pleural cavity. The records of our Hospital (No. 3 Canadian General) show a protest by the Commanding Officer of our surgical division regarding the arrival of certain patients with wounds packed with B.I.P.P. and yet having their superficial dressings changed and soaked every four hours with Dakin's solution.

In spite of such fearful procedures it was noted that, particularly when pressure of work prevented meddlesome interference, a large number of the B.I.P.P. cases were arriving in much better shape than those treated by any other method.

During the spring of 1918, one of us (L. H. McK.) had the privilege of being associated with Mr. Morison for a number of days

* From The Montreal General Hospital.

during which time he visited certain medical units in France to demonstrate the essential principles in his technic. Among the advantages claimed for the method are:

1. Relief of pain.

2. Stimulation of a healthy reaction on the part of the tissues and control of original infection.

3. Infrequent dressings with consequent: (a) Avoidance of secondary infection; (b) avoidance of pain; (c) economy of dressings; and (d) conservation of time of both surgeons and nursing sisters.

For the achievement of these desiderata a thorough understanding and careful application of certain principles and points of technic are necessary. These are:

1. Mechanical cleansing of the wound with removal of all obviously dead tissue and also such tissue as seems likely to necrose.

2. Secure a *dry* wound. This must be accomplished not only by control of gross bleeding by means of ligatures or pressure, but by dehydration of the wound surface with alcohol in order to permit the necessary and complete application of the B.I.P.P. and liquid paraffin to all parts of the wound, with special reference to deeply placed interstices. Only thus is "curtain drainage" effective.

3. Complete relief of tension in the wound. We must remember that the primary object of incising an infected area is to improve circulation through the part by relief of interstitial tension and not to simply evacuate pus. We have made it a practice not only to carry out whatever division of skin and subcutaneous tissue and more particularly of fascia may be necessary to relieve tension already established, but to extend such incisions sufficiently to anticipate such inflammatory swelling as may be expected.

4. Rub B.I.P.P. thoroughly into all parts of the wound and then remove any excess with dry gauze. The amount that can be used is important. If large quantities be left in a wound poisoning, either by bismuth or iodoform may of course result. As a rough guide it may be said that not more than a desertspoonful (2 drams) should be used in any case. If all excess be removed, there remains but little danger. If a large area (more than 144 square inches) is to be covered, one may dilute with liquid paraffin. If there are multiple wounds whose total area seems likely to exceed this danger limit, we prefer and recommend that the use of B.I.P.P. be reserved for the more serious or the more grossly contaminated wounds and to treat the less important by other less effective measures such as the Carrell-Dakin method, or the use of aqueous acriflavine packs.

5. Carefully *pack* the wound with soft gauze soaked with liquid paraffin and containing a little B.I.P.P. Insistence must be placed on the tightness of the packing and that it reach to the bottom of the wound. A dead space behind the packing is likely to persist as a focus of infection. Here the pack acts not as a drain but as a plug.

6. Apply dry gauze dressings and bandage. Secure adequate rest of the part by plaster or other methods of splinting.

7. Watch the patient. In general, there is an early relief from pain. Moderate fever for three days is not alarming. Severe pain, persistence of high temperature for a longer period or toxic symptoms demand investigation.

8. If oozing through the dressing occurs, pour on a little alcohol and reinforce the dressing.

9. Dress in six days to three or four weeks, usually under anesthesia, especially for the first dressing. The importance of keeping watery solutions away from these wounds must again be stressed. Secondary infection will nearly always result. The use of hydrogen peroxide is particularly to be avoided, and similarly Dakin's solution and other tissue solvents. The reason for the sudden flare-up of infection in the wound after the use of these materials is possibly due to the destruction of protective thrombi in lymph and blood vessels.

The question of "curtain drainage" has been referred to and may need some explanation. The principle is best demonstrated by pouring some water on a piece of glass and noting how smoothly the glass is covered. Let us now take another clean piece of glass and pour on it some oil. Even if the oil is wiped away, it will be found that a thin coating still adheres to the glass and the water cannot cover it smoothly. This same reaction occurs in the application of liquid paraffin to wounds in the tissues. If the wound is carefully dried and dehydrated so that close application of the liquid paraffin to the tissue is insured, and if, in addition, the wound is tightly packed *to the bottom*, the small amount of blood or serum will reach the skin surface along the curtain of liquid paraffin which exists between the tissues and the gauze packing. It is to be noted that the oil used must be a nonabsorbable mineral oil.

The formula of B.I.P.P. and it's preparation deserve some attention. The paste is composed of one part bismuth subnitrate with two parts of iodoform (powder) and sufficient liquid paraffin to form a paste. Stress must be placed on the use of liquid paraffin and not vaseline. The use of vaseline will result in a greasy ointment which will not adhere to the tissues.

The arguments advanced against the use of B.I.P.P. are many and varied. One of the most common is that it is impossible to sterilize any wound by chemical methods without serious damage to the tissues. Hence, certain surgeons have developed an almost fanatical prejudice against "putting chemicals into wounds." We would like our names to be associated with a campaign against a probably greater danger of "putting water into wounds," and this includes the injection of local anesthetics. In this connection, I would like to call your attention to the statement by no less an authority than Dr. William Darrach, who in a recent paper made the following statement, having special reference to compound fractures: "The wound itself and any exposed tissue should be greatly washed with saline solution, care being taken not to allow the fluid to enter the deeper planes."

In regard to preoperative care of wounds in general, we have always believed that the mechanical cleansing of wounds was, if possible, much better accomplished by other means than by the washing of wounds with watery solutions which must of necessity carry into the wound itself the ever present bacterial flora of the skin. We have no fear of the frequently mentioned danger of tissue necrosis by the application of alcohol to wound surfaces. We have never believed that this matter was of any great importance nor have we ever seen any ill results from its use. We would like to point out that none of the advocates of the B.I.P.P. treatment have ever claimed that wounds were sterilized by this method and we are quite prepared to admit that no wound can be sterilized by chemical means. We do claim, however, that this material has certain very positive actions. These are:

1. Inhibition of bacterial growth.

2. The liberation of small amounts of iodine over a long period. This action was shown many years ago to be due to the liberation of iodine by the oxygen in the wound and in the blood stream. It has also been proven that there is a liberation of a small amount of nitric acid by hydrolysis of the bismuth subnitrate. Iodine has been recovered daily from the urine for as long as three weeks after the application of B.I.P.P. to a wound.

The work of Anderson, Chambers and Goldsmith, in 1917, has never been disproven, while evidence, both clinical and laboratory, has many times confirmed their findings. While wounds treated in this manner are not free from bacteria, they show a marked reduction in the bacterial count and those present do not seem to be able to

proliferate freely. There seems to be a definite stimulation of the bodily resistance of the individual which enables the wound to heal frequently as if it never had been infected. In other words, there is very little doubt that this method of treatment enables the bodily resistance to be markedly raised. As there is almost invariably a large amount of serum thrown out along the layer of liquid paraffin "curtain drainage," we have always inclined to the belief that the wound was stimulated to pour out increased amounts of serum and that this lymphorrhea had the effect of washing bacteria from the wound and that it also increases the available supply of whatever immune bodies—alexin and other—the body fluids contain. One thing is certain, there is undoubtedly an extremely early formation of healthy granulation tissue, of which the character, color and general behavior toward healing are very distinctive.

As an indication of the importance that this method of treatment is once more assuming, it may be noted that in a recent Hunterian lecture before the Royal College of Surgeons of England, Mr. James H. Saint reviewed the B.I.P.P. method of treatment of acute osteitis. Mr. Saint calls attention to the so-called Winnett-Orr method and its similarity to the B.I.P.P. method. We believe his paragraph on this subject is worthy of quotation:

"This is placed under a separate heading because, owing to Orr's publications (1927) it has become known by his name and seems to have been accorded the status of one which apparently differs from any other. Since, however, it consists of the gutter operation, the treatment of the wound with alcohol followed by iodine, the packing of the wound with vaselined gauze, and the immobilisation of the affected part, its similarity to the B.I.P.P. method of treatment becomes at once apparent. At the time, towards the end of the late war, when Orr was formulating his method of treatment, the B.I.P.P. method was already established and widely practised in the British Armies. While the principles of this method are the same as those governing the B.I.P.P. method—namely, the removal of the bony focus of infection, the use of an antiseptic and immobilisation, and it has the same advantage of obviating the necessity for frequent dressings—yet it is different in one or two important details. In the first place, the iodine as used by Orr will be absorbed in a very short time and no further supply will be available under his method of treatment. The use of B.I.P.P., on the other hand, results in a continuous supply of nascent iodine to the tissues as long as the paste is present in the wound."

In confirmation of the statement made above, we think it is fair to state that both the authors of this paper had personal experience with the use of the B.I.P.P. method during the latter part of 1916, and that one of us (F. B. G.) published in 1918 an article which was based upon a study of wound healing in a large number of cases of osteitis treated by different methods and in which the employment of B.I.P.P. and liquid paraffin soaked gauze packs was recommended. Perhaps the most impressive difference between wounds treated by vaseline gauze packing and liquid paraffin soaked gauze plus B.I.P.P. is the comparative absence of odor in the latter even after many weeks.

### TOXIC SYMPTOMS

During the twenty-one years since the close of the first phase of the war, although we have in the "L" service of The Montreal General Hospital used the B.I.P.P. method in the treatment of thousands of wounds, both traumatic and infective, we have yet to see an important case of either iodoform or bismuth poisoning in a patient so treated. We have, however, seen a moderate number of cases which have exhibited a bismuth line on the gums but without further evidence of poisoning. During the years 1917 and 1918 a few wounded soldiers did die of bismuth poisoning. The lesions found at autopsy in their cases consisted of a metallic stomatitis with necrosis of the mandible and an extensive ulcerative colitis. Fortunately, it is true that a superficial stomatitis or gingivitis antedates the development of serious lesions by several days and opportunity is thus given to remove all of the paste before dangerous symptoms ensue. To the best of our knowledge, neither of us has ever seen a fatal case of iodoform poisoning.

### USES IN VARIOUS TYPES OF WOUNDS

We believe B.I.P.P. may be safely and effectively used for the following types of wounds:

1. Acute traumatic lesions whether due to gunshot wounds, automobile injuries or construction accidents associated with potential infection and with particular reference to compound fractures. In the less severe types of wounds of this sort we may occasionally do a complete primary closure. We believe, however, that a delayed primary closure is nearly always advisable. This adds a considerable factor of safety and very little time is lost. When the loss of tissue has been great so that delayed primary suture is impossible or

when there is moderate infection, we use secondary suture or make use of various plastic procedures for filling the defects.

2. Infected wounds. These may be the results of untreated trauma or infection of operating wounds.

3. As a prophylactic measure against the infection of the body wall in the opening of certain infected cavities, notably, (a) abdominal abscesses—appendiceal or otherwise; (b) empyema or lung abscesses; and (c) operations on the mastoid or other deep seated abscesses.

## SUMMARY

1. This paper is presented to bring attention to a valuable method of wound treatment.

2. A detailed technic is given.

3. A thorough understanding and careful application of the principles of this technic is necessary.

4. More than twenty-three years experience is military and civilian surgery have served to confirm the authors of this article as to the value and safety of this method.

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## DISCUSSION OF PAPERS OF DR. KREUSCHER AND DRS. FRASER B. GURD AND LAURIE H. MCKIM

ROBERT L. RHODES (Augusta, Ga.): Speaking first of Dr. McKim's paper, I want to express my appreciation of hearing it. I have had no experience with Bipp and therefore am not qualified to discuss it, but I think we can find some use after hearing that particular paper. I want to thank him for bringing it in such detail to our attention.

In regard to Dr. Kreuscher's paper, I may say he beat me to a place on the program. I submitted a title, "Twenty Years' Experience with Chloramine-T." I am glad he did beat me because he expressed my thoughts and ideas infinitely more effectively than I could, and I can only say "Amen" to everything that he has said.

I wish to remind you of one thing. If we recall, soon after Dakin's solution was first worked out, Dakin showed that there was a rapid fall of chlorine after the wound was flushed, a drop almost to the base line, then a second rise, which required over two hours to expend itself. That secondary rise occurred so often than he began an investigation as to why it was, and found that it was due to a definite chemical compound having been formed to which he gave the name chloramine-T, not dichloramine-T. That is another product, soluble in oil. Chloramine-T is water soluble. That was brought out in 1916. In this country the Abbott Laboratories, in Chicago, presented it first to the medical profession under the trade name of Chlorazene, and they are still making it.

Incidentally, a very prominent industrial surgeon recently made the statement that chloramines had fallen "into relative disuse." I checked upon this and the Abbott people themselves sold over a quarter of a million pounds of chloramine-T products during the last year, so it evidently has not fallen into disuse, and they are only one of several makers.

The advantage of chloramine-T over hypochlorites, or true Dakin's solution in which the margin of antiseptic factor as shown by Dakin was 0.05 per cent (between 0.45 and 0.5 is the correct amount of sodium hypochlorite concentration), is its prolonged effect even as it is being gradually diluted in the wound.

He showed that chloramine-T has all the effects of true Dakin's solution save one, and that is that it does not have the property of dissolving necrotic material and they changed to chloramine-T after all necrotic matter was removed. It is stable, nonirritating and germicidal over a prolonged period. I have tested it in dilutions as far as one to five thousand and found very definite bactericidal effects.

It was first introduced, as I said, under the name Chlorazene. It was accepted by the Council on Pharmacy and Chemistry and included in the U. S. Pharmacopoeia under the name of chloramine-T.

I am bringing out those points because the market in the last several years has been flooded with proprietary or patented preparations which more or less are the same thing or are strikingly similar to U. S. P. chloramine-T but cost appreciably more.

Our experience with the use of chloramine-T over a period of twenty years is so strikingly analogous to what has been brought out, that I need not repeat that at all. But let us not overlook the fact that "chemical sterilization" is third in the steps of handling wounds and was so recognized in the "Carrell Dakin Treatment" preceded by "mechanical cleansing" and "surgical cleansing" (debridement). These two should carry 95 per cent of the burden and leave only about 5 per cent to "chemical sterilization." In industry and accidents generally today there is no excuse for the delay of the injured in reaching the surgeon as existed in the World War.

I recently sent to the members of the Association for the Surgery of Trauma three reprints, with two thoughts in mind: First, as a discussion of two of the papers presented last year, and incidentally they happen to be a discussion of this particular paper this morning; but primarily for this reason: to show to the members of this Association what we in Georgia are trying to do through the State Medical Association in bringing these problems to the general practitioner. The one relative to compound fractures was part of a symposium on fractures presented by the State Fracture Committee of the American College of Surgeons, covering the subject of fractures. The other was presented by the Georgia State Industrial Surgeons Association. The aim was to try to educate the doctor at large in the handling of these injuries, or in the getting of the injured into the hands of somebody competent to handle them, rather than, as so often happens, sending them in dabbed and smeared up with various irritants and in infinitely worse condition than they were at the time of the original injury. It seems to me that one of our functions should be, after we have thrashed things out, to take the results back to our State Associations and present them there with the emphasis of the Stamp of Approval by this Association.

W. L. Estes, Jr. (Bethlehem, Pa.): I believe that these papers have been most timely and valuable.

I believe we would all be in agreement concerning the general principles under which fresh wounds should be treated; namely, (1) control of hemorrhage, (2) prevention of any further contamination of the wound, (3) thorough gentle mechanical cleansing of the wound, preferably with soap and water and saline, (4) enlargement of the wound, if necessary, so that all parts may be completely visualized, (5) very gentle handling of tissues to prevent further trauma, (6) removal of all foreign bodies and débris, (7) débridement—the careful, thorough, and complete removal of all devitalized tissue (which Dr. Kreuscher so well emphasized), (8) accurate hemostasis with fine ligatures, (9) closure of wound—primary or delayed, (10) drainage, and (11) immobilization of part.

Furthermore, it is not only what is done, but also how it is accomplished, how thorough and painstaking these methods are pursued, that determines the success of the end result, namely, primary healing and a clean wound. However, I believe that we cannot safely apply a blanket treatment for all types of wounds. Wounds, as it is so well recognized in many other surgical lesions, must be individualized. The type of contamination and the severity of muscle and bone damage, particularly, call for variation in treatment.

It was a great step forward to have demonstrated that with thorough mechanical cleansing of a wound and the removal of all devitalized tissue, no antiseptic was needed to prevent infection; as normal living healthy tissue in itself is adequate to prevent infection of the wound when all possible nidus for growth of bacteria has been removed. Many antiseptics are tissue irritants and tend to delay healing because of their destructive action on healthy tissue.

However, the question was raised in a discussion last year on this same subject before this Association, as to the advisability of the use of an added safeguard, especially in the soil or anaerobically contaminated wounds with their particularly virulent bacteria, such as gas and tetanus bacilli; i.e., the use of some nonirritating but effective antiseptic in addition to the routine measures for treatment of wounds.

I think those of us who are dealing frequently with industrial wounds will recognize the difference with which we can regard an industrially acquired wound and that from an agricultural or soil environment as far as the type of contamination is concerned. Certainly we expect to find in the industrial wound much less serious contamination than in the soil contaminated wound.

It was suggested that Dakin's solution was a satisfactory antiseptic for use in these severely contaminated wounds and a small series of cases was reported in which it had proved effective without apparently causing any delay in healing. We have continued its use this year and find we have used Dakin's solution in about 40 per cent of the wounds presented to us for treatment in the last year. I do not think that this is necessarily a cross-section of what we would routinely or actually use, every year, year in and year out. The use of an antiseptic must depend on the type of wounds submitted for treatment and upon the judgment of the surgeon as to what treatment each particular type of wound requires.

With an extensive laceration of muscles, particularly with an open or compound fracture, delayed closure of the wound and effective immobilization are imperative. After cleansing and débridement the wound may be packed with vaseline gauze, liquid paraffin, or Bipp paste, according to individual preference. Dr. McKim has emphasized the indications for the use of Bipp paste. That long immobilization in these cases, without dressings or with but few dressings will permit more satisfactory and rapid

healing was Orr's particular and important contribution. Carrel-Dakinization of the wound may well be an alternative method, or, as has recently been suggested, sulfanilamide locally in the wound may be effective.

Those whose experience or contacts have made them partial to a certain method may find it renders them particularly skillful in its application, and satisfactory results with it will be obtained. It seems to me, therefore, that we should have at our command not simply a routine treatment to be applied to each fresh wound, but also certain variations in treatment which will best answer the problem that each particular wound presents. Indications for their use may differ, but that method should be applied to each wound which will obtain the best results.

These two papers have been important in demonstrating at least two optional methods that are worthy of consideration when attempting to solve the problem of the treatment of a fresh wound.

R. Arnold Griswold (Louisville, Ky.): In discussing these two very excellent papers, I should like to express my belief that it is a relatively small proportion of wounds in which it is necessary to carry out this type of treatment. In the type of wounds under consideration, that is, ordinary street and industrial wounds, at least 95 per cent can be closed primarily and will heal without infection. In the other 5 per cent these methods, Bipp, vaseline gauze, or Dakin's solution are necessary. This 5 per cent includes wounds over eight hours old or those in which the surgeon's judgment, on account of excessive contamination or massive destruction of soft tissues, primary closure is not advisable.

We all agree, I think on the principles of the primary care of these wounds, thorough cleaning and removal of all foreign bodies, whether they consist of dirt, blood clot or devitalized tissue. But we do disagree on the details of this débridement and cleansing proposition. This is not a procedure to be carried out in fifteen or twenty minutes in the office or accident room. Proper cleansing of a major wound is a major operation which should be carried out with all the ritual and technic of a gallbladder or thyroid operation. All foreign bodies, whether they be dead tissue, blood clot or dirt must be removed. Hemostasis must be obtained. For arterial hemostasis it may be necessary to use a few fine silk ligatures, but venous bleeding can be controlled by pressure in most instances.

I have never been afraid to put aquaeous solutions in a wound, since the body fluids themselves are aquaeous, but in putting them in they should flow from the inside of the wound to the outside and they should not be put in with a pitcher or by squeezing out a sponge but with a hose and nozzle. The nozzle should be put in deep and the flow of the irrigating saline should be out and away from the depths of the wound, using Henry Marble's galvanized iron pan to catch the flow.

No sutures are used beneath the skin except for nerves and tendons, that is, no layer suturing of fascia and muscle. Nerves and tendons may

be approximated with a few fine silk sutures and the skin closed only with interrupted silk.

I think if this cleansing procedure is faithfully and meticulously carried out in the way that neurological surgeons carry it out, these wounds will heal primarily without being packed open or irrigated.

This procedure can be carried out successfully not only by one who is enthusiastic about it, but by the ordinary hospital house staff as illustrated by a case seen recently. This patient was driving with his whole hand and arm out of the car window when side-swiped by a truck. He apparently attempted to straight-arm the truck and his hand was driven backward on the forearm, the distal end of the radius coming out the palm of his hand. About one and one-half inches of radius was left on the roadside. There also was a compound fracture of the ulna and metacarpals and a few phalanges and irregular lacerated wounds from the base of the fingers half-way up the forearm. An assistant resident, two years on the surgical service, cleaned up this arm did his débridement and irrigation and closed the wounds tight. At the end of ten days the patient was fever free, the temperature never having gone over 100°F. The wound healed by primary intention without any packing, open or Dakin irrigations.

Therefore, I believe that with proper surgical judgment 95 per cent of the type of wounds which we have under consideration here can be closed primarily and get a better end result than healing by secondary intention with the increased amount of scar that secondary healing brings with it.

CLAY RAY MURRAY (New York City): I am afraid I cannot let what Dr. Griswold said about these papers go by without offering some objections.

Before I discuss what he had to say and, incidentally, what the papers had to say, I should like to emphasize one point in the treatment of wounds, particularly important in compound fractures, which has not been emphasized very strongly. That is the question of the speed with which the patient is gotten from the accident to the operating room. I think that probably, all factors considered, this is the most important factor in deciding whether a wound is going to become infected or is going to heal cleanly, regardless of the method of treatment. I think delay in treatment of the wounds in compound fractures is more often responsible for infection than is the type of treatment the wound is accorded.

In my own hospital, after a campaign of twelve years, we have reached the point where a compound fracture has precedence over all other emergencies in the operating room. I think this is a proper attitude. I think this point needs to be emphasized very strongly. The initiation of the treatment in wounds, particularly compound fracture wounds, should be estimated in *minutes* from the time of accident and not in *hours* from the time of accident. I think that the difference between an hour and three hours is a tremendous factor in deciding whether under any method of treatment the wound is or is not to become infected.

Secondly, I approve very thoroughly of the principles which were enunciated in the Bipp method of treatment for compound wounds. One must admit that if you exercise good surgical judgment in a majority of wounds you can close them and "get away" with it.

I do not believe in boasting about what you can "get away" with. I know—I don't "think"—I know that in the 5 per cent, even, that Dr. Griswold is willing to admit you do not "get away" with, when they develop infection it represents frequently a major disaster.

Jack Connor, some years ago, at Harlem Hospital, ran two series of cases, one hundred cases each, of compound wounds, all of which in the judgment of the operator, could be closed primarily. In the first hundred cases the wounds were so closed, after adequate débridement; conditions were identical for the second series except that no primary closure was done.

In the first series, with the wound closed primarily, seven infections developed out of the hundred; in the second series of cases with wounds left open and closed secondarily with delayed suture, eight infections developed one more than in the closed wounds. Of the seven infections developed in the closed cases, one patient died of septicemia, amputation was carried out in two cases and every patient except one developed osteomyelitis. In the eight cases left open and therefore not under tension, there wasn't a single case of sepsis, no amputation, and only one osteomyelitis.

I think the question is not whether you can "get away" with a wound open or closed in the majority of cases. The question is what happens when you do not "get away" with it. I have never been able to understand why a wound healed by secondary intention in a compound fracture is a distressing thing for the doctor or the patient. I do not believe the healing by secondary closure is any defect in treatment at all. I refuse to bet my judgment against the patient's leg even though the odds on the bet seem excellent. When he loses, the patient's loss is out of all proportion to what he has to gain, which is a week or two or three of extra hospitalization. I, therefore, do not believe that a compound fracture should be closed primarily.

I will admit it can be done and you can "get away" with it usually. I do not believe that a wound in which sutures are placed at the time of operation, with the wound closed by tying these sutures at the end of five days, delays the patient's convalescence materially or gives poorer results. I know it is a much safer procedure.

E. T. Crossan (Philadelphia, Pa.): In 1919, Sir Almroth Wright made the statement that if there was any antiseptic that cleared up infection, that fact deserved to be broadcast with headlines in all the newspapers. He was referring particularly to the Bipp method and the Carrel-Dakin treatment.

These papers recall experiences because during the World War I had under my care at times about one hundred patients on the Carrel-Dakin method of treatment, and it was supervised by disciples of Carrel and Dakin, taught at their institution and of course it was handled with most meticulous care; yet my memories are in agreement with what Sir Almroth Wright said would happen. In spite of the method those patients were dressed day after day and the pus poured out for weeks. To Sir Almoth Wright there was nothing disheartening in those failures for he proved that when Dakin solution or Bipp paste was introduced into a wound, within a few moments the antiseptic was so diluted by the wound fluids, that it was no longer lethal for the bacteria.

Since hearing these papers, maybe I should have resumed the use of the Carrel-Dakin method. I discarded it after I left the service, and I have not used it since, because my results, too, have been satisfactory, and they have been satisfactory without antiseptics and without scrubbing the wound at all. We make no attempt to scrub or shave a wound. We think you cannot do it without contaminating a wound. Perhaps it is the locality that we are in that is responsible for our getting good results in this movement.

I have only seen two cases of gas gangrene in twenty years, and I have a big service in a big city hospital. Because of my luck I had been closing all compound wounds and closing them up until one time there was a discussion between the Philadelphia Academy of Surgery and the New York Surgical Society, at which time Dr. Beekman took me for a ride because I was closing these wounds, and said, "What would you do if it was your leg?"

Well, I know what I would do. I would fear I might be among the 5 per cent Dr. Griswold spoke of, and I would be afraid I might lose my leg; so you can guess the treatment I would want.

I want to emphasize regarding the treatment of wounds something that has not been mentioned at all and something I find the magazines speak very casually about; that is, the subject of tetanus. No mention of it has been made. It is assumed that one prophylactic dose will do, but one is not sufficient. I have just had on my service a second case of tetanus in two years in spite of the fact that the patient had a prophylactic tetanus antitoxin.

I want to emphasize that it seems to me the good results obtained are due to the care with which we are handling the wound and not to what we use in the wound.

FENWICK BEEKMAN (New York City): I do not wish to prolong this discussion, but Dr. Crossan, I think, has brought me in and put me on the spot. We, in New York, have gas gangrene. Apparently that discussion we had in Philadelphia some ten years ago has stuck. They do not have gas gangrene down there.

Since that time I think all of us have changed our views on the treatment of wounds. I, for one, have done away with antiseptic treatment of wounds. I have been laying a great deal of stress recently on the complete immobilization after the preparation of my wound; and, by "preparation of my wound" I mean what has been described here, preparing the wound for further treatment, that is, your débridement and cleaning up, which I agree with entirely.

The question of closure of the wound, or the secondary closure of the wound, depends upon the experience of the surgeon, the case under consideration and his judgment in that case.

In a compound fracture of the skull I think all of us could do a primary closure, but where there is a compound fracture of the tibia, I think that I agree with Dr. Murray. I think it is safer for the individual to do a secondary closure.

I have carried the immobilization of wounds much further than most people have. We get on the Children's Surgical Service at Bellevue a large number of avulsions of the skin of the limbs, where the skin and subcutaneous tissue are entirely torn off, leaving the muscles exposed. We take those children to the operating room and prepare them, and then we put them in complete immobilization, and when I say "complete immobilization," I mean we put them in a plaster cast. For instance, the leg, if there is an avulsion around the knee, we put a plaster cast on from the toes and continue it right up to the chest as a spica. I think we have not laid enough stress today on rest.

I remember when I was a student, J. William White used to tell us that rest was most important. We did not know what rest was in those days, but since the day when Orr first came out with his ideas on the treatment of compound fractures, which none of us agreed with at the time, some of us have carried the method further than he had, and I am using immobilization in all my severe wounds in an active traumatic service.

GROVER C. WEIL (Pittsburgh, Pa.): I am very sorry I came into the meeting a little late but in view of the importance of the subject, I feel that I should at least report a method we are using at the present time, in fact, for the past year.

It has been our belief in reference to compound fractures—I come from an industrial community where contamination of wounds is quite heavy—that we have always adhered to the open method, long before Orr popularized the idea, immobilization, fixation and, of course, packing the wounds.

Our preliminary cultures have always shown essential contamination with gas bacillus and staphylococcus, and the various staphylococcic forms and in a large industrial service, from the point of view of economy and safety to the patient and eventual return of function, it has always proved in our hands the most efficient method.

Of recent date we have been using sulfathiazole; at first sulfanilamide, then sulfamethlythiazole, and since its discontinuance, we have been using

sulfathiazole. The extent of the experience to date, of course, is too small, even though we have had over a hundred cases; nevertheless, it deserves a tryout, but I think the results obtained by introducing the powder immediately into the wound and then following with fixation and immobilization, is well worth while in reciting our experience.

The results obtained to date have been perfectly marvelous in those cases in which we have used sulfathiazole, depending upon the size of the wound as to the amount to be introduced. We implant and use the powder throughout the entire wound and also administer it by mouth. Our previous low cultures always showed potential contamination. The use of this method has permitted us to close our wounds to a point now at which we believe it can be done with safety, shortening the period of convalescence and permitting the healing of the wound and unionization without interference of infection. That is the thing we desire, the prevention of infection and the unionization of wounds.

We also have deep respect for a therapeutic dose of gas bacillus antitoxin, and we do not forget the possibility of tetanus.

PHILIP H. KREUSCHER (closing): I wish to thank the men for their discussion of this paper. It is only the difference of opinion which makes a discussion possible and profitable.

When selecting a method of treatment for any given condition, one must first have faith in the method and enthusiasm concerning it and not simply use a certain method or preparation because some one has suggested it. Every method of treatment must be molded in the hands of the surgeon who is going to use it and must have as its purpose the best interest of the patient.

In these industrial wounds our primary aim is to get them to heal with the least amount of scar tissue, the least morbidity and the least disability.

A number of years ago when I took up my work with the steel corporation I decided upon this method and believed that it should be used for a period of years until results could be evaluated. In these three and one-half years we have had results that are completely and entirely satisfactory, and we are going to stand on our record of three infections in 26,000 wounds.

LAURIE H. McKIM (closing): May I thank those who have discussed this paper for their very kindly remarks. I may say we are possibly slightly disappointed that we did not draw a little more fire. However, that will probably come.

I want to refer just to one or two things: I am afraid I cannot agree with Dr. Griswold that 95 per cent of the wounds can be closed with safety. Certain of my friends have believed in that doctrine and the thing has not worked. I agree very strongly with what Dr. Murray has said about the time between the injury and the treatment of wounds, especially compound fractures, and, believe me, in any hospital where that principle is disregarded, the results will be correspondingly bad.

Dr. Crossan has mentioned the second dose of A.T.S. There is no doubt whatever about its value, in my mind, and I have always practiced it since the War.

In regard to the occurrence of gas gangrene and tetanus, I purposely did not mention them because I felt they might be covered in the other paper and in any case it would be better to take them up separately. The subject is much too wide for such a brief consideration.

We do have in Montreal considerable tetanus and a fairly large amount of gas gangrene. Last year I had under my care three cases of gas gangrene at one time. I am glad to say that none of these had been primarily treated by me. One occurred in a man with a diabetic toe.

As to the question of the various chemicals such as sulfanilamide, I have had very little experience with their use directly in wounds.

I think this covers practically everything I have to say in order to bring the discussion to a close.

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*Note:* Dr. James C. Magee, Surgeon General of the U. S. Army, also gave an address at the Meeting of The American Association for the Surgery of Trauma in Atlantic City, June, 1940.

# FIFTEEN YEARS OF THE TANNIC ACID METHOD OF BURN TREATMENT*

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IN spite of the fact that the tannic acid method of treatment of burns advocated by Davidson in 1925[1] has virtually revolutionized the treatment of burns throughout the world, the method has received much unfavorable criticism. It may be in order, therefore, for those of us who have had an unusual opportunity to study the method to present the data which we have accumulated during the past fifteen years.

In previous communications,[2,3] we have outlined the method of treatment in detail and have analyzed the statistical data that were then available. In the present discussion we shall attempt to evaluate our own experiences and those of others as recorded in the literature as they tend to answer the question, "Is the tannic acid routine the most satisfactory method of burn treatment at present available?" At the same time, we shall consider the various modifications of the coagulation routine as they appear to affect the results. It seems reasonable to discuss as a part of the tannic routine various procedures that have been developed subsequent to Davidson's work, since it was his conception of the problem which stimulated the studies that have lead to many variations of the coagulation method.

One of us had been working on the burn assignment at St. Luke's Hospital for several years prior to 1925 and had been using with considerable enthusiasm the "Ambrine"[4] (paraffine spray) method which had been adopted following the War. Prior to that we had used exposure to dry heat under a cradle, baths of warm solution and various oils and ointments. It was with some reluctance that we tried the coagulation method of Davidson in 1925, but after a few weeks we began to be impressed with the following observations: (1) that the patients so treated were more comfortable, requiring very little sedative; (2) that they were much easier to care for; (3) that they did not seem as ill as those treated by other methods.

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The final answer to the effectiveness of primary treatment of burns rests with the mortality rate. Unfortunately, not many critical studies of the effect of the coagulation method upon mortality have been made upon large numbers of patients, and large numbers are necessary to minimize error. Burns do not, moreover, lend themselves to statistical study. It is impossible to compare accurately burns as to surface involved (even using the method of Berkow)[5] and the depth of the burn may be a matter only of conjecture by the most experienced observer. Furthermore, the severity of burns varies from year to year in any community, and the criteria for admission to hospitals may vary similarly.

Table 1 shows the mortality trend with tannic acid and other methods of treatment collected from the literature. Practically all observers who have attempted to compare their results statistically have reported a significant decrease in mortality with the coagulation method.

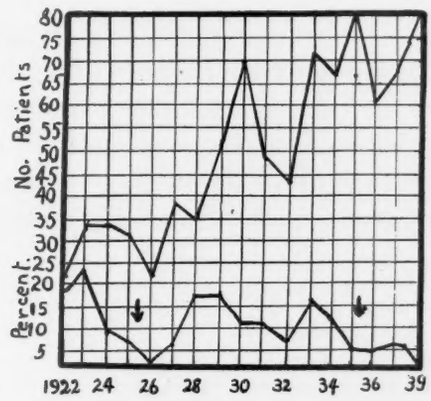
TABLE 1
TREATMENT OF BURNS
Comparative Mortality with Tannic Acid and Other Methods

| Author | Other Methods | | Tannic Acid | |
|---|---|---|---|---|
| | No. of Patients | Mortality Per Cent | No. of Patients | Mortality Per Cent |
| Bancroft and Rogers (New York)[6] | 90 | 40.0 | 114 | 20.0 |
| Beekman (New York)[7] | 320 | 37.8 | 114 | 14.9 |
| Wilson (Edinboro)[8] | 300 | 38.7 | 117 | 11.1 |
| Harris (Toronto)[9] | .... | 26.6 | .... | 12.0 |
| Mason (Phila.)[13] | 91 | 28.5 | 87 | 13.3 |
| Langer (Vienna)[10] | 86 | 16.3 | 65 | 7.7 |
| Mitchiner (London)[11] | 243 | 9.4 | 249 | 2.4 |
| McClure and Allen (Detroit)[12] | 118 | 9.3 | 358 | 11.7 |
| Glover (Cleveland) | 121 | 14.0 | 809 | 8.4 |
| Total patients | 1369 | .... | 1913 | |
| Average mortality | .... | 24.5 | .... | 11.3 |

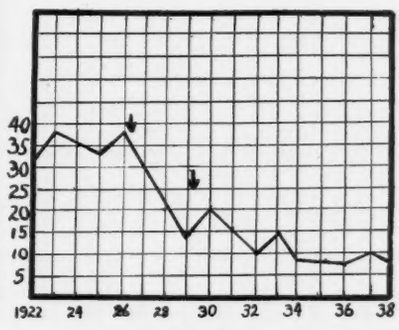
From these figures it would appear that if the patients in the tannic acid group had been treated by other methods, 252 would have died who actually survived.

In the figures quoted from our own series, we have used the same criteria throughout the entire interval of nineteen years before and after the use of tannic acid. The indications for admission of patients with burns to the service have remained the same throughout except that in all probability there has been a tendency to hospitalize more

burns in the later years of the series than in the earlier years, as physicians have become educated to the efficacy of hospital treatment. Generally speaking, all burns of sufficient extent to constitute




GRAPH 1.




GRAPH 2.

GRAPHS 1 AND 2. The mortality trend by years. In Graph 1 the upper curve represents the number of burn patients. The lower line indicates the mortality rate by years. The first arrow indicates the beginning of the tannic acid routine. The second arrow indicates the addition of silver nitrate to the routine. In Graph 2, the interval between the arrows indicates the use of tannic acid experimentally, but subsequent to the second arrow it was used routinely. Graph 1 is from the authors' series, Graph 2 from the series of Penberthy and Weller, Detroit.[14]

any hazard to the life of the patient or that presented any difficulties in treatment were admitted. Burns of the eye, minor chemical burns, hot water-bottle burns and others that were complications of hospital treatment were excluded, as were those which were incidental to another injury necessitating hospitalization.

Particularly significant is the mortality trend by years from the beginning of the series in 1922 to 1939. The decline in mortality since the beginning of the coagulation regime seems too impressive to be discounted. Comparison of our Graph 1 with that of Penberthy and Weller[14] in Graph 2 shows a similar trend.

Study of the deaths in the series is productive of significant data. It was shown by Beckman[7] and one of the authors[2] previously that the late deaths following burns were relatively fewer than with other methods of treatment. In other words, the chief reduction in mortality rate in the tannic acid series comes after the first twenty-four hours.

Table 11 shows the causes of death in our St. Luke's Hospital series. It will be noted that the major number of deaths are attributed to the toxic period during the first three days following the

burn. (This includes the periods of "primary shock," "secondary shock" and "toxemia" of Wilson;[16] but the latter would probably include the deaths we have classified as late toxic and cardiac collapse within the interval of "toxemia.")

Over one-half of all the deaths occurred during the first twenty-four hours. Of our mortality rate of 8.4 per cent for the series, over 4.2 per cent of deaths occurred on the first day following the burn, due to overwhelming injury. We believe it is significant that the mortality rate during the first twenty-four hours has not been greatly altered by any method of treatment. (We reported previously

TABLE II

TREATMENT OF BURNS

St. Luke's Hospital Series

Patients 809 Deaths 68 Mortality 8.4 Per Cent

| Causes of Death | Deaths | |
|---|---|---|
| | No. | Per Cent |
| Toxic. (This includes all patients who died due to the effects of the burn within the first seventy-two hours. It includes deaths that would be classified by others as due to "shock." In two instances hemorrhage into the intestinal tract may have contributed.) Three-fourths of these deaths occurred in the first twenty-four hours | 44 | 64.7 |
| Delayed toxic and cardiac collapse (fourth to seventh days) | 14 | 20.6 |
| Thromboses and pulmonary emboli | 4 | 5.8 |
| Late vascular and cardiorenal complications | 3 | 4.4 |
| Hemorrhage from Curling's ulcer | 2 | 3.0 |
| Suicide | 1 | 1.5 |
| | 68 | 100.0 |

a similar rate for the series without tannic acid.) It is, therefore, in the later days of treatment that we must look for reduction in our mortality rate. It will be noted in our series there were no late deaths due to infectious complications. There were fourteen deaths due to a delayed toxic effect or sudden cardiac collapse between the fourth and the seventh days. Thrombophlebitis, pulmonary embolus, late vascular and cardiorenal complications and hemorrhage from Curling's ulcer made up a small percentage of the causes of death, and one patient committed suicide successfully in the hospital after setting fire to himself in the first place.

We believe that the coagulum serves the following important functions during the first few days following the burn: (1) It fixes the

protein in the burned tissue and prevents the hypothetical "*b*-substance" from being absorbed; (2) it prevents dehydration; (3) it prevents infection; and (4) it keeps the patient comfortable. If this conception be correct, the speed of coagulation is an important item, pointing the need for prompt treatment and the use of coagulants that will produce the quickest results.

TABLE III

TREATMENT OF BURNS

Comparison of Burn Deaths in Hospitals *A* and *B*

(Covering the interval from January 1, 1935, to December 31, 1939)

| | Hospital *A* | Mortality Per Cent | Hospital *B* | Mortality Per Cent |
|---|---|---|---|---|
| Number of burn patients | 362 | ... | 227 | |
| Number of burn deaths | 16 | ... | 31 | |
| Gross mortality | ... | 4.4 | ... | 13.6 |
| **Causes of Death** | | | | |
| Death during toxic period | | | | |
| First 24 hours | 10 | ... | 13 | |
| Second 24 hours | 2 | ... | 1 | |
| Third 24 hours | 2 | ... | 1 | |
| Total in toxic period | 14 | 3.8 | 15 | 6.6 |
| Late toxic and cardiac collapse | 1 | ... | 4 | |
| Late infectious compl. (incl. pneumonia) | 0 | ... | 10 | |
| Late vascular compl. (incl. pul. embol.) | 1 | ... | 1 | |
| Late hemorrhage | 0 | ... | 1 | |
| Total late deaths | 2 | 0.6 | 16 | 7.0 |

Table III shows comparative results in two series of patients in Cleveland Hospitals during the same five-year interval, with early and late deaths tabulated.

In Hospital *A*, burns have been handled in a systematic manner, using the coagulation regime almost exclusively for fifteen years, and almost all patients were treated as emergencies and tanned promptly. In Hospital *B*, the clientele is of a poorer economic group with its greater physical handicaps which must contribute to mortality figures. But in this group also many of the burns were brought to the hospital late and more variations in methods of treatment were followed, although the majority were treated with tannic acid and silver nitrate. We believe that the delayed treatment and in some

cases ineffectual treatment contributed to the higher incidence of late deaths from infectious complications, especially pneumonia.

This brings us to a point where our experience has been at variance with that of Davidson, who believed that the coagulum should not be disturbed too early for fear of precipitating a secondary toxic response. Our experience leads us to believe that in all but the very superficial burns the coagulum no longer serves a useful function when it begins to separate and it should be removed in the most effective and expeditious manner. This is accomplished most effectively by continuous dressings of Dakin's solution. It is this particular stage of the treatment that has brought much criticism against the method because "infection develops under the crust."

From five to eight days after treatment is begun, the coagulum begins to separate from the surrounding skin edges exposing a gelatinous exudate. At the same time the center of the coagulum may begin to elevate and become fluctuant, and the patient's temperature goes up. (In superficial second degree burns the crust merely cracks off at about ten to fourteen days leaving intact epidermis while in deeper burns the process is much slower.) If at this stage continuous Dakin's solution dressings are applied (using an active and stable preparation), the temperature will go up to a sharp peak for a few hours; then it will drop down and remain at a level between 38 and 38.5°C. until the crust is all off and the granulating surface covers rapidly with epidermis, or until it is ready to graft. If instead, the surgeon vacillates between leaving the coagulum alone and getting it off, the patient becomes desperately ill, runs a septic temperature, develops a secondary anemia and all too often some infectious complication appears. It is in this stage that we see the most trouble among physicians who treat burns only occasionally.

While the crust is dry and tight, microscopic sections show it as a layer of dermis and sometimes subcutaneous tissue incorporated in a dense coagulum, with a narrow inflammatory zone beneath which lies normal tissue. This normal appearing underlying tissue may be grossly edematous before the tissue is dehydrated and fixed. The maximum local edema resulting from the burn is usually found between the second and the fifth day and begins to recede by the sixth or seventh day. As the tissue edema recedes, the coagulum cracks and buckles and in some areas "floats." The inflammatory zone widens and liquefies producing a gelatinous exudate which increases in amount, gradually floating off the eschar. Organisms may often be grown out of this gelatinous exudate, although unless

neglected the bacterial growth is not rapid. If the coagulum is left undisturbed at this stage, however, the patient runs a clinical course similar to that of an infected wound.

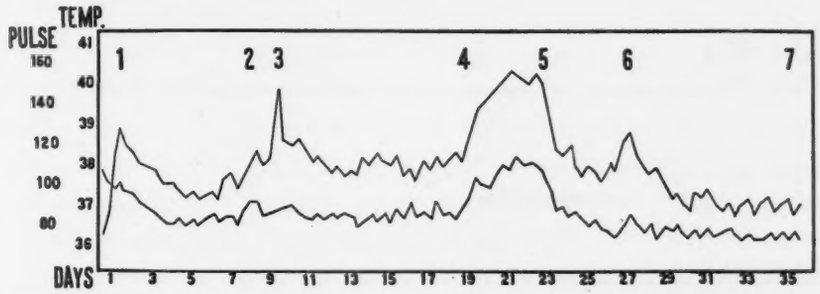



CHART 1. Typical temperature and pulse curve in a severe burn. 1, initial rise, followed by drop when surface is coagulated. 2, coagulum begins to separate. 3, Dakin's dressings started. 4, change to boric acid dressing. 5, back to Dakin's. 6, skin graft. 7, healed.

The Dakin's solution liquefies the gelatinous exudate, helps to break up the coagulum and inhibits bacterial growth. If the Dakin's solution is *not fresh* or is *not continuously in contact* with the surface of the wound, it does neither. We have previously described the details of management of this stage[2,3] and will not repeat it here. The length of time required to separate the entire coagulum will vary from twenty-four hours to three weeks depending upon the depth of the burn. It is essential that the Dakin's solution be fresh and of proper hydrogen ion concentration. Referring again to the comparative Table III, it seems quite possible that some of the difficulty shown in the control of secondary infections has been due to Dakin's solution which is not consistently effective, a difficulty which has been recognized but not controlled in that institution.

Chart 1 illustrates graphically the clinical course of a severe burn and shows the reaction which results when an ineffectual type of dressing is substituted for Dakin's solution.

To recapitulate, we believe that the data herewith presented argue strongly in favor of Davidson's original hypothesis concerning the value of the tannic acid coagulum during the first days of burn treatment, but against his second hypothesis that to disturb the coagulum when it is beginning to separate incites a recurrence of the toxemia. While the coagulum may be life saving during the early days of treatment, it may be a menace during the later period.

## ETIOLOGICAL FACTORS

Although experimental work has clarified some of the effects of severe burns, we are still unable to say what is the lethal factor.

The hypotheses concerning the cause of death may be grouped under the following headings: (1) physical; (2) toxic, and (3) infectious.

Underhill[17] and his associates popularized the physical theory,

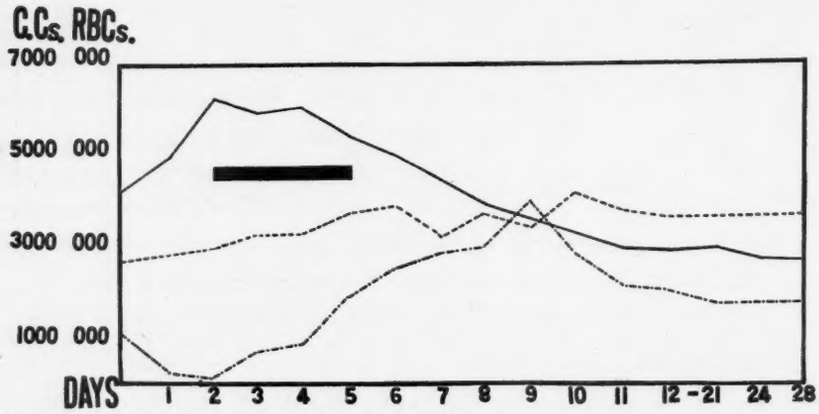



CHART II. Fluid balance in the severe burn. The solid line indicates the number of red blood cells; the dashes indicate fluid intake and the dots and dashes urine output. The solid block in black indicates the presence of albumin, casts and red cells in the urine.

assuming on the basis of their experimental data that the lethal effects of burns were due to blood concentration resulting from sudden displacement of fluid from the blood stream to the site of injury. There is ample experimental and clinical evidence[16,18–20] that following the severe burn there is a marked increase in permeability of the capillaries at the site of the burn, resulting in rapid loss of fluid, plasma protein, chloride and sodium from the circulating blood. A shock-like state supervenes as well as blood concentration. It has not been possible, however, to produce liver necrosis, which appears to be typical of the burn effect, by other methods which will cause marked fluid and plasma displacement. From a clinical standpoint it is difficult to explain burn deaths upon the physical hypothesis alone. Some burned patients die without showing any shock-like phenomena and without manifesting any significant degree of blood concentration. During the stage of blood concentration and decreased urine output, furthermore, it is virtually impossible to combat effectively blood concentration by intravenous administration of physiologic solution of sodium chloride, dextrose, or by whole blood. Attempt to force fluids at this stage inevitably produces generalized edema. Chart II shows graphically the state of fluid balance in a severe burn. We have not had an opportunity to use plasma transfusions. On the basis of theoretical consideration

plasma transfusions should be ideal for replacing plasma proteins without increasing red cell concentration.

The toxic theory has also had many supporters. It has been assumed by several investigators that a histamine-like substance (sometimes called "*h*-substance"), perhaps a split protein, is liberated at the site of the burn.[1,16,19] No such substance has been isolated, however. Recent studies suggest that potassium may be the mysterious "*h*-substance."[34] The fact that the coagulation routine reduces the mortality from severe burns may be accepted as suggestive evidence in favor of the toxic theory. It has thus far been impossible to produce liver necrosis in animals by histamine alone, as may be produced by injection of blister fluid or edema fluid from the burned area. There is some inconclusive experimental and clinical evidence that individuals or animals may have their tolerance to the effects of burning increased by repeated exposure to similar injuries.

The infectious theory advanced by Aldrich[25] now has few proponents. It is almost inconceivable that the major number of burn deaths which occur during the first twenty-four hours could be caused by bacterial invasion.

## THE COAGULATING AGENT

If we are correct in the premise that early coagulation of the wound influences mortality, it should follow that the more rapid the cogulation the more effective the treatment will be. Of all the coagulating combinations suggested thus far, tannic acid and silver nitrate produces the quickest results. By this combination a good coagulum is formed and is relatively painless in thirty minutes. It will be noted that in Graph 1 the mortality trend has dropped since the addition of silver nitrate to the tanning routine.

Seeger has called attention to the fact that the depth of the tanning process is influenced significantly by the hydrogen ion concentration of the tannic solution. He has advocated an isotonic formula for the tanning solution[28] which has been modified by Fantus and Dynewicz.[29] We have confirmed Seeger's observations that the rapid tanning with the ordinary 10 per cent tannic acid with low hydrogen ion concentration does not tan completely the deep third degree burns and that his slower method of tanning penetrates deeper. We have not followed enough cases using his method to be of significance statistically. Criticism and condemnation of tannic acid because it does not penetrate[30] to the depth of a third degree burn does not impress us as too serious an objection, since it is

common observation that the deep burns are already fairly well coagulated by the burn producing agent. It has been frequently observed, experimentally and clinically, that fire burns produce less local edema than hot water burns, which may reasonably be due to the greater degree of immediate coagulation by the flame. Critics[31] of tannic acid have also stated that it destroys unburned epidermis in the process of coagulation. Admitting that this may be a fact (although we have failed to confirm it), if tannic acid saves lives while destroying a few epithelial cells, it is still a desirable method of treatment. We have seen no conclusive evidence that the coagulation method interferes with the healing process.

Ferric chloride was suggested by Coan[32] as a desirable coagulent which produced a pliable crust. If used in aqueous solution, however, it is slow acting and if used in the more effective alcoholic solution, it is painful.

Gentian violet and subsequently a combination of dyes were originally suggested by Aldrich because of their bacteriocidal properties. They have been used fairly widely with satisfactory results reported, but no statistical studies are available. These dyes are fairly satisfactory coagulants, but are slower acting than tannic acid and silver nitrate.

### OTHER METHODS OF TREATMENT

Cod liver oil has been advocated as a primary burn treatment.[33] Its chief virtues are apparently pain relief and a theoretical value as a stimulant to epidermal growth. There is no evidence to show that it has any value in minimizing the constitutional effects of a severe burn and it is unpleasant to handle.[15] Periodically a new burn ointment will be concocted and advocated in the literature on the basis of a brief trial on a few animals and "brilliant" results in a handful of patients. We know of no such preparations at the present time that possess any particular virtue. Warm continuous baths are advocated from time to time but we know of no statistical studies on burns so treated.[27]

In this connection a word about tannic acid jelly might be in order. In 1927, we began using a 5 per cent tannic acid jelly in tragacanth base with enough boric acid to keep it from decomposing. The idea was soon taken up by the pharmaceutical houses and there are now a number of such preparations on the market each containing its own proprietary antiseptic and bearing a trade name. These preparations are useful for ambulatory burns and those about the

face where the spray is impractical. To the best of our knowledge and experience the proprietary antiseptics add nothing to the effectiveness of the preparations.

### DÉBRIDEMENT

In some hospitals it is customary to do an elaborate débridement of the burn before spraying with tannic acid and silver nitrate, sometimes anesthetizing the patient and using a scrubbing brush. This is unwarranted and may produce enough shock to leave the patient unable to cope with the damaging effect of the burn. Only gentle cleansing and removal of grease which can be done without shock and with a minimum of pain should be practiced, while opening blebs and peeling off damaged epidermis. Even gross particles of carbon are not worth removing if to do so will traumatize and shock. These particles are all incorporated with the coagulum and come away with it. We have seen no instance of infection that could reasonably be attributed to such a source.

### CHEMOTHERAPY

Sulfapyridine has been used with benefit by Penberthy and Weller.[14] It has not been used in our series.

### SENSITIVITY TO TANNIC ACID

In our experience with the hospital series recorded in this communication and a much larger number of ambulatory burns, we have encountered eight instances of acquired sensitivity to tannic acid. These patients developed a dermatitis upon application of tannic acid jelly, in one instance with severe constitutional symptoms. In all instances patch tests were positive. Each of these patients had been treated several years previously with tannic acid. Fortunately, these were trivial burns, and we have not thus far encountered an instance of sensitivity in a severely burned patient. These occurrences, though rare, point the way to the advisability of obtaining a history of treatment of previous burns with tannic acid and patch testing in doubtful cases.

### STATUS OF TRANSFUSIONS

In the St. Luke's Hospital series very few transfusions were used. It has seemed hazardous to add whole blood to a vascular system already suffering from cellular concentration. The chief

benefit to be obtained from whole blood would seem to be the addition of needed plasma proteins and oxygen carrying cells to an individual who is anoxic from the cellular concentration. Plasma transfusions seem more logical.

### HORMONE OF THE SUPRARENAL CORTEX

Experimental and clinical evidence of hemorrhage or cellular infiltration into the suprarenal cortex has been frequent following severe burns, but not by any means constant. Wilson[24] and Einhauser[34] have reported experiences with the use of desoxycorticosterone acetate (synthetic preparation of the hormone of the suprarenal cortex) in severe burns. We have used it in too few instances to be significant. From experimental data which implicate the suprarenal cortex in the damaging effect of burns with apparent loss of sodium ions into the burn site, and accompanying rise in K-ions, it seems likely that this effect is only one link in the chain of burn effects and not the causative factor. This angle of the problem merits further investigation.

### SUMMARY AND CONCLUSIONS

1. Data are presented from the authors' series of 809 hospitalized burns and the observations of others which tend to confirm the value of the coagulation regime as a valuable method in burn treatment.

2. The theories of causation have been briefly reviewed.

3. Some of the important factors in treatment have been emphasized.

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## DISCUSSION

Fenwick Beekman (New York City): This paper of Dr. Glover is very timely because he has reviewed most carefully a large series of cases treated by the tannic acid treatment. From time to time we hear people introducing new methods of treatment for burns, but in my hands I have found that the tannic acid still holds first place, and I am going to show you some figures which are almost exactly the same as Dr. Glover's.

Table 1

| Dates | No. of Cases | No. of Deaths | Mortality, Per Cent |
|---|---|---|---|
| **Before Tannic Acid Treatment** | | | |
| June 1919–Nov. 1925 | 320 | 89 | 27.8 |
| **Tannic Acid Treatment** | | | |
| Dec. 1925–Aug. 1928 | 114 | 17 | 14.9 |
| Sept. 1928–Jan. 1, 1940 | 518 | 36 | 6.9 |
| Dec. 1925–Jan. 1, 1940 | 632 | 53 | 8.5 |

This is in no way a slight of hand trick, because Dr. Glover and I, I think, have never met before, but after I was asked to review his paper, I looked up our figures for the last ten years, and you will be surprised to see how much alike they are. (Table 1.)

In this first Table 1 show you our records before we introduced tannic acid, with a mortality rate of 27.8 per cent. Then I show you a mortality of 14.9 per cent, in 114 patients treated up to 1928 with tannic acid; and then I show you 518 cases treated up to the present time, from 1928, with a mortality of 6.9 per cent, giving a mortality for the whole series of tannic acid cases, of 8.5 per cent. I believe Dr. Glover's was 8.6 per cent. (Table II.)

Here we have divided our tannic acid treatment into three periods, the first period, of four years, with 14.9 per cent mortality; the second series, of five years, 7.7 per cent mortality; and the third period of five years, 4.3 per cent mortality.

Now, during this period our technic has changed slightly. In the original 117 cases we used a tannic acid solution without any further additions. We used a certain amount of fluids, intravenous fluids, but it was not until Underhill came out with his papers that we really commenced to go into

the treatment of burns in a more scientific manner as to body fluids, and I think that might show something toward the improvement that we had in this next five years. Then five years ago we started to add silver nitrate to tannic acid, to get a more rapid treatment, and we have reduced our mortality rate again down to 4.3.

I believe that these figures are not as honest, perhaps, as they might be, for I have also believed that the type of burns we have been getting has not been (that is, all of them) as severe as those we formerly had.

Now, as to the removal of the eschar, this is a point on which I am afraid I shall have to differ with Dr. Glover. Our experience is that if the wound (burned wound) is properly cleansed before the application of tannic acid, we seldom obtain infection under the eschar. The surest way to inoculate your wound with infection is to make a hole through that eschar to inquire as to whether there is infection under it.

TABLE II
CASES TREATED WITH TANNIC ACID

| | No. of Cases | No. of Deaths | Mortality, Per Cent |
|---|---|---|---|
| 4 yrs. {1926 ... 1929 | 177 | 25 | 14.9 |
| 5 yrs. {1930 ... 1934 | 249 | 19 | 7.7 |
| 5 yrs. {1935 ... 1939 | 206 | 9 | 4.3 |
| Totals | 632 | 53 | 8.5 |

In the last five or six years we have been painting the edges of our eschar, that is, at the line of demarcation, with gentian violet solution in the hope that that would prevent the entrance of infection.

We have not seen much infection. Where infection is proved, we immediately remove the eschar.

Tannic acid treatment of burns has been of great advantage to the healing of the wound because, as soon as the tanned area is separated, grafting can be done without any further preparation of the granulating surface.

I want to thank Dr. Glover for showing his figures to us, for I believe that the tannic acid treatment of burns is the best treatment that has so far been introduced for that purpose.

GROVER C. PENBERTHY (Detroit, Mich.): It is a great pleasure to have this opportunity to discuss Dr. Glover's paper because of the fact that he has really epitomized the treatment of burns from the standpoint of the use of tannic acid. In his clinic he has made a very careful analysis of his

cases. His mortality figures represent a meticulous interest and work in carrying on and caring for all the details surrounding the management of a severe burn.

One cannot approach the treatment of burns such as he has described without assuming a great responsibility, not only in the prevention of early shock by the use of sedatives, but also by the careful preparation of the wound which Dr. Glover and Dr. Beekman have emphasized.

That is important. Individuals who have criticized the use of tannic acid because of the associated infection, I think, have not properly prepared their wounds, and here again I disagree with Dr. Glover, as did Dr. Beekman with regard to the early removal of the coagulum. I think Dr. Glover has misunderstood to some extent the work of the late Dr. Davidson with whom I worked prior to his death.

Doctor Davidson found in a certain number of patients who were treated with the moist dressing because of the appearance of pus, that a certain number so treated had a return of the toxic symptoms. Because of that observation we delayed removing the crust and did not apply moist dressings.

Dr. Glover did not have an opportunity to go into this complication thoroughly. He did say, however, that following the removal of the coagulum with early application of the moist dressing, there was an elevation in the temperature. That was what Doctor Davidson assumed to be a manifestation of the return of the toxemia. For that reason, we did not use moist dressings to loosen the coagulum. The coagulum should be removed, however, in the presence of pus and it may require anesthesia to remove it. The third degree wound can then be prepared for early skin grafting.

There are many factors that enter into the lowered mortality figures: One is the careful attention to the wound, which must be treated as a surgical wound; and, secondly, the interest that has been taken by clinicians treating burns in order to work out a technic which will aid in lowering the mortality.

This study that we are carrying on at Wayne University, is a little aside from the question, but, nevertheless, it enters into this problem of mortality, and I wish to report that at the present time we are making a study of the plasma protein, hematocrit, and plasma and cell potassium in severely burned patients.

The series of cases at present is small and the potassium studies have not been completed; however, some of the findings to date are worth mentioning. The most marked increase in the venous hematocrit occurs during the first six hours. During the following twelve hours there is a gradual increase and very little increase after that time.

One patient, burned over the entire body, had a hematocrit of 70 per cent at the end of the first hour, which indicates that he had lost approximately one-half of his plasma volume.

We have found that giving 5,000 to 6,000 cc. of saline intravenously per twenty-four-hour period causes a marked drop in plasma proteins, frequently to the edema level. Intravenous blood plasma decreases the hemoconcentration more effectively without causing a drop in the plasma proteins. Whole blood given with moderate amounts of saline will tend to prevent a marked drop in plasma proteins but does not bring the hematocrit down as rapidly as plasma. Burns involving a third or more of the body are now given 1,000 cc. of blood plasma and 1,000 to 2,000 cc. of glucose and saline by vein. The remainder of the patient's fluid is given by mouth.

We have also had the opportunity of making postmortem examinations on a small number of burn cases, but have found very little. Occasionally there is a mild necrosis of the liver and usually a bronchopneumonia is present, but we have found no changes in the adrenals and we have seen no thrombosis or hemorrhage in any of the organs.

In referring to infection, in a small series of cases treated at the Children's Hospital of Michigan we have used sulfapyridine with some apparent good results. Many of these patients, as reported in the postmortem findings, show evidence of a bronchopneumonia, upper respiratory infections and infections about the wound. We have treated only a small series with sulfapyridine, but we think that this form of therapy may be a factor in reducing the morbidity and mortality.

HENRY C. MARBLE (Boston, Mass.): I am like Dr. Murray, who could not get beyond the seventh inning on the subject of compound fractures, and when the seventh inning came, I had the same urge he had.

I listened to that paper before about the treatment of wounds and everyone agreed the one thing he wanted to do was to perform a decent débridement, and then there were three roads; one went the road of Bipp, one went the road of bichloride, and another the road of salt solution; in other words, they agreed on the fundamentals. I thought that was grand. And haven't we got to go into that before we have the fundamentals? The treatment of the burned patient is the treatment of the patient.

Recently some experimental work has been done on the effects of thermal trauma on dogs. A dog had been submitted to thermal trauma. One dog had been given adequate anesthesia; the other dog was given no anesthesia. The dog with adequate anesthesia lived a great deal longer than the dog with no anesthesia.

I have heard but one fleeting word about the use of morphine. The burned patient has to have adequate sedation, and the burned patient has a tremendous outflow of serum and plasma. Immediately there is hemoconcentration, the red count goes up and the next battle must be to control his hemoconcentration, give him plasma salt solution and transfusion. This must follow and go hand in hand with the sedation. That is fundamental.

The patient must be treated, must have his morphine, must have his saline, and must have transfusions of blood to take care of the concentra-

tion. Then we come to the point, after we have treated the patient and have kept him alive: We turn to the three ways of the local treatment which, though it may seem heresy, I would think would be the least important, because the patient dies of sepsis. The patient dies as a result of his burn, and whatever treatment you give does not alter that, I believe.

I am always entertained when people talk about the new treatment of burns, about tannic acid; and if you would look into the works of Confucius, you would find that he painted them with a strong solution of tea; that would cover one side of it. Then if you read the works of Hippocrates, you find that—well, Dr. Sherman would be happy when he learned that Hippocrates put beeswax and balsam on his wounds.

So this same thing as to what we are going to put on the wound, has been discussed since the turn of the century and we are still going ahead, except that now in the matter of tannic acid we have brought in the matter of infinite pains, and the improvements we see in the charts I think are the results of infinite pains in the use of that method, which is an excellent method; but we must not forget in the use of tannic acid that the fundamentals are that the patient must have good nursing care, the patient must have morphine, the patient must have sufficient fluids, and then draw a line. Those are the fundamentals. Then whatever form of treatment you are going to apply, do so with infinite pains, and I think you will get the same results.

HUBLEY R. OWEN (Philadelphia, Pa.): One question, I want to ask is whether Dr. Beekman uses silver nitrate solution with tannic acid, with incipiency of treatment, or whether he does not find it too painful to use in early treatment.

DONALD M. GLOVER (closing): I appreciate very much, gentlemen, the kind of discussion that has been given. I will answer first the last question, about the use of tannic acid and silver nitrate together. If one uses a tannic acid spray for about twenty minutes, there is an immediate precipitation of protein, and a brownish-white coagulum begins to appear or form; then 10 per cent silver nitrate is almost painless and produces quick coagulum, which in about twenty minutes is pretty tight.

I am glad that some of the points have been brought out which I had to pass over to keep within the time limit but which appear in the published paper. The importance of fluid balance has been so much emphasized that a certain amount of inconsistency has developed in an attempt to overcome blood concentration with an enormous amount of fluid in the treatment of burns. As Dr. Penberthy showed a moment ago, edema is produced and there is displacement of normal plasma proteins as a result of protein loss at the site of the burn, due to increased capillarity permeability. Fluid alone is not enough and it is probable that plasma transfusions may be part of the answer. We have hesitated to use blood transfusions extensively because whole blood added to the blood already the seat of cellular concentration, would seem hazardous. Given with caution, transfusions have

been helpful, probably because they have added oxygen-carrying tissue and blood proteins badly needed as a result of their loss from the circulation.

Dr. Penberthy mentioned the work with the potassium level. The recent experimental work suggesting suprarenal damage in severe burns has been suggestive; however, I do not believe that any one believes that the suprarenal cortex is the essential factor of the damage in the burn. The use of oxycorticosterone acetate is apparently helpful during the stage of shock and perhaps later. We have used it in only a few instances, not enough to be conclusive, but I believe this angle of the problem is one that deserves further study.

I quite agree with Dr. Marble's remarks about the treatment of the patient generally, and there is no question at all in any of our minds relative to the organization of the method of treatment of the patient as a whole. The part the organization of the hospital for systematic treatment plays in the outcome may possibly be as important as the type of treatment itself. I cannot agree with Dr. Marble upon the use of morphine, however. Burns treated with tannic acid require very little morphine.

We tried to be fair in evaluating all of the items and after we were through, we were still of the opinion that the coagulation routine contributed significantly to the results.

# TRACTION PARALYSIS OF THE BRACHIAL PLEXUS

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MENTION of the subject of traction paralysis of the brachial plexus immediately suggests to the audience the question of brachial birth paralysis. This association of ideas is the result of our surgical education. We have been taught to believe that the question of paralysis of the brachial plexus is one that one sees chiefly in obstetrics. The nearly total neglect in the leading literature of paralysis of the brachial plexus in the adult is seen from the appalling fact that the most popular American reference book on surgery, written by a number of teachers of various surgical specialties, gives the question of paralysis of the brachial plexus in the adult only thirty-five lines, while brachial paralysis of birth is discussed in fifty-six pages of an average of forty lines each. The only treatise that deals justly with the question of injury of the brachial plexus in the adult is the one by Stevens, a practitioner of general surgery, published in Codman's monograph on the shoulder. These facts bring to mind a recent statement of Leriche: "Surgery will be engulfed in technical byzantinism on the day when it has become a mosaic of specialties." In America, this day is rapidly approaching, not without the help of the American Board of Medical Specialties.

The present discussion concerns only plexus paralysis due to traction. Paralysis due to direct injury to the plexus or due to pressure is not considered here. Traction paralysis may be caused by direct or indirect traction on the plexus, as for example, by blows that depress the shoulder, falls with the arm suspended or falls on the shoulder with the head turned to the opposite side, or by dragging one by the arm. Obviously, one cannot enumerate all the various ways of exerting traction on the brachial plexus that one is apt to see in industrial or traffic mishaps.

The time honored classification of paralysis of the brachial plexus according to the involved roots distinguishes the Erb-Duchene paralysis, with involvement of $C_5$ and C6, the Dejerine-Klumpke paralysis, when C8 and D1 are affected and the complex type. This

classification is of little practical interest. It is a legacy of investigators who limited their studies to birth injuries of the plexus. While in birth injury the paralysis is frequently radicular in distribu-

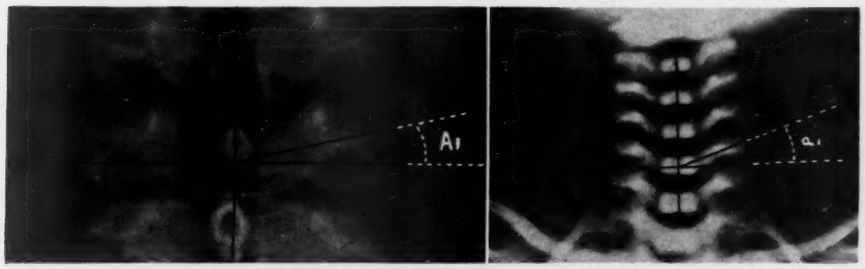


FIG. 1. Radiogram of cervical spine of the adult and of the newborn. Showing the difference in the direction of the transverse processes. In the adult the angle (A) is only one-half of the angle (*a*) in the newborn.

tion, traction paralysis in the adult is of a truncular distribution with sensory disturbances in the foreground.

The pathologic anatomy and the clinical picture of traction paralysis of the brachial plexus are better understood when one considers the three main anatomical sites where, theoretically, the elements of the plexus may become injured as a result of traction: (1) The spinal canal; (2) the bony gutters formed by the transverse processes, and (3) the region between the exit of the roots from the bony gutter and the exit of the neurovascular cord from the axilla.

Theoretically, traction on the roots within the spinal canal may cause an avulsion. While avulsion has been demonstrated in the newborn, the literature contains no authentic case of avulsion following traction in the adult. The widely accepted opinion of the frequency of avulsion in the newborn is deeply rooted, notwithstanding the frequent clinical observations of a return of motor function following the diagnosis of "avulsion." My suspicion of this claimed frequency of avulsion was first aroused by the fact that the same well known photograph of an infant with an avulsion of several cervical roots, shown first by Taylor some twenty years ago appears in late major treatises on the subject by other authors. This is an example of stereotyped information taken for granted by subsequent writers without due criticism.

Why does traction on the brachial plexus occasionally cause avulsion in the newborn and not in the adult? The answer to this question is twofold: First, the traction on the plexus at birth is different from that in industrial and traffic accidents. In a difficult delivery the obstetrician is apt to be overwhelmed by one idea, and

that is to see the infant outside of the birth canal. The pressure exerted on the infant's shoulder and the plexus is firm, direct and prolonged in distinction to the indirect and brief traction in accident.

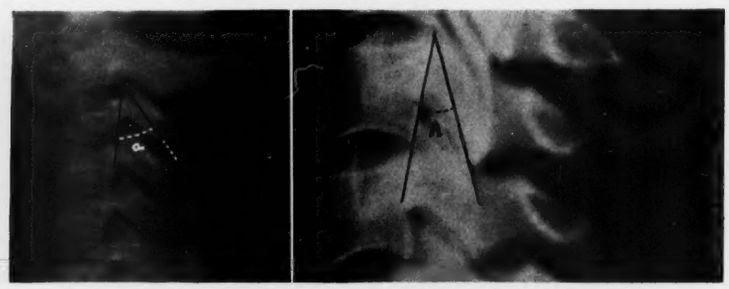

FIG. 2. Showing in a lateral view the difference in the direction of the transverse processes taking place with age. In the adult the angle formed by the longitudinal axis of the transverse process with the axis of the vertebral body (A) is only about one half of that in the five year old child (*a*).

Second, the course of the bony gutter and of the root in the newborn differs radically from that in the adult. I have learned this fact from anatomical dissections. Since I failed to find mention of it in texts on anatomy I have prepared photographs demonstrating these points. (Figs. 1, 2 and 3.)

In the cervical spine, beginning with C3 the upper aspect of the transverse process carries the deep sulcus nervi spinalis. This sulcus follows the axis of the process. In the newborn the transverse process is directed upward. The scaleni muscles, which take their origin from the transverse processes of C3 down, gradually, with age, pull the transverse processes downward and thus change their angle with the spinal axis. A number of other long muscles taking their origin on the transverse processes contribute to this gradual change in the direction of the processes. Obviously, the spinal root running within the sulcus nervi spinalis also changes its course. Thus, in the newborn the cervical root is under a higher tension normally, since it must "circumnavigate," so to say, the tip of the transverse process before turning downward in the neck to the point of joining the plexus. Additional pull on these roots at delivery may suffice to cause an avulsion. Besides, the root is not as strongly snubbed at the transverse process in the infant because of a poor development of the fascial tissues. This brings us to the second site of possible injury to the roots as a result of traction, the bony gutters.

On its way through the bony gutter the root is sheathed by the dural sleeve which protects it there from extrinsic pressure by hemorrhage. Theoretically, therefore, the only traction injury of the roots

within the bony gutter is a rupture of the root. Such a rupture is extremely rare; it has been mentioned, although not definitely proven, in cases where the impact on the shoulder was enormous and

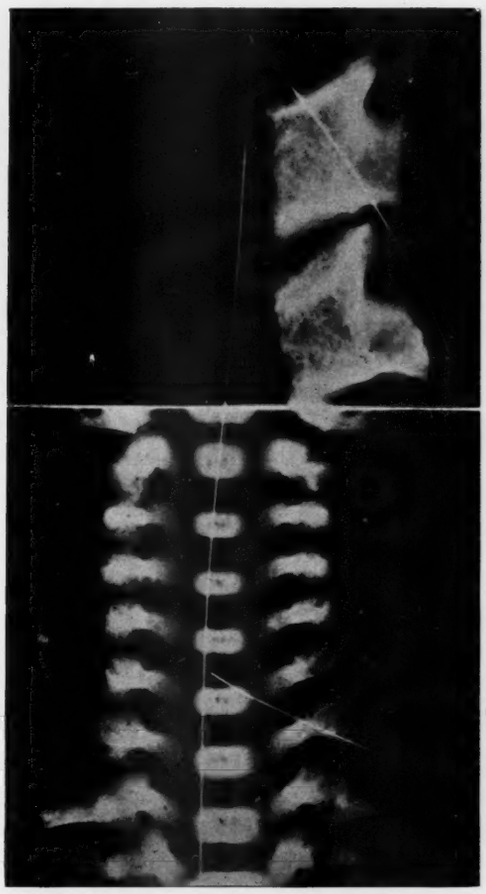

FIG. 3. Showing the change in the incline of the sulcus nervi spinalis taking place with age. A fine steel wire was passed through the sixth cervical root in the adult and in the newborn.

sudden, with the shoulder carried by an immense force down and back. The anatomical reasons for the rarity of rupture of the roots within the bony gutter are pointed out by Stevens. The roots of the brachial plexus are held firmly at the transverse processes and in the sulci by invagination of the prevertebral fascia which snubs the root at the process. This snubbing takes the strain away from the roots during traction on the plexus. (Fig. 4.)

Because of the reasons pointed out above traction injury to the plexus in the adult is usually limited to the part located distally

to the bony gutter. True rupture of the plexus is extremely rare. One finds in the literature a score of reports of rupture of one or more roots of the plexus. However, scrutiny of these reports shows

FIG. 4. Photograph of the left half of a portion of the cervical spinal cord (B). Showing the snubbing of the sixth cervical root (A-A) at the transverse process (C). (D) is the dentate ligament between C6 and C7.

that the majority of them are based on "hear-say." The reasons for this infrequency of rupture are mechanical. The force causing traction will first be broken by the skin, the muscles, the tendons and the ligaments; then, it is distributed to all fascial investments of the neck and axilla. Thus disseminated the force is reduced considerably and by the time it is transmitted to the underlying plexus it has lost most of its punch. But, while the continuity of the plexus remains intact, the investing fascial structures together with the numerous blood vessels about the plexus are traumatized severely in breaking this blow and a hemorrhagic infiltration of the surrounding tissues follows.

The brachial plexus is situated in an inverted pyramid the base of which rests on the cervical spine and the apex, at the point where the neurovascular cord enters the axilla. This pyramid is bordered by the clavopectoral fascia, the prevertebral and the deep cervical fasciae. The hemorrhagic effusion about the plexus spreads through the pyramid as in a funnel; it gravitates toward the armpit and accumulates within the fascia surrounding the plexiform part of the neurovascular cord. Numerous ecchymoses are seen also throughout all the fascial investing sheaths of the individual nerve fasciculi. If not removed, the exudate remains there until absorbed, causing numerous adhesions about the nerve bundles. Thus, while the neurovascular cord is usually more severely scarred than the individual roots, the lesions are never strictly limited; the infiltration of blood is wide and the resulting pathology diffuse so that there is no practical reason for a distinction between lesions of the roots and lesions of the plexiform portion. These findings explain why traction paralysis of the brachial plexus is nearly always of the complex type rather than the individual Erb-Duchene or the Dejerine-Klumpke types, and why the paralysis is one of a truncular rather than radicular distribution. Since the lesion is one of constriction rather than interruption in continuity, sensory disturbances are in the foreground.

Because traction injuries of the brachial plexus are occasionally accompanied by injuries of the skeleton the physician, particularly if he is a narrow groove specialist, will usually overlook the plexus injury or at best will treat it as a stepchild, paying most attention to the fracture, the dislocation or the "torn ligaments." The injuries to the plexus gradually progress so that the pains which accompany the causalgia of the plexus become especially severe months after the accident. As the adhesions increase their strangulation of the nerve bundles the motor paralysis becomes more marked. Later, the pain may decrease in intensity but the paralysis will not diminish. The erroneous opinion that the paralysis clears up spontaneously is drawn from cases of paralysis caused by pressure upon the plexus and not by traction. If pressure is not prolonged to the point of causing ischemia of the nerves, the paralysis will clear up.

The pathologic anatomy of traction paralysis as outlined above dictates the proper management of these patients. In the early cases, treatment should aim at a speedy relief of pressure upon the plexus by the hemorrhagic exudate, so as to prevent adhesions and strangulation of the nerve bundles. In the late cases radical dissection of

the scarred plexus and liberation of the strangulated nerve bundles is called for. It is obvious that delay of surgical treatment in these cases is prejudicious to the patient's interest. In trained hands an exploration of the brachial plexus above and below the clavicle is fully safe and justifiable.

In a widely known reference book on "Traumatic Surgery" the author advises to wait "four months to two years" before operating upon these patients. This advice is the result of a lack of distinction by the author between paralysis of the brachial plexus following pressure and that due to traction. Paralysis resulting from pressure will promptly clear up if the pressure did not cause ischemic degeneration of the nerve fibers. To operate in cases of pressure is, therefore, either needless surgery in cases of moderate pressure, or useless surgery in cases of prolonged pressure. There will be an occasional instance when rupture of a nerve root is diagnosed beyond any doubt. These rare cases are best left alone, since suture of a nerve root seems to be a forlorn hope.

### ILLUSTRATIVE CASES

CASE I. B. K., a man, 28 years old, was loading furniture when a heavy table fell on his right shoulder depressing it and forcing his head to the left. Because of a fracture of the acromion, the shoulder was immobilized for several weeks. Persistent complaints of "pins and needles" in the arm and hand went unheeded until atrophy of the small muscles of the hand led to the correct diagnosis eight months later when the brachial plexus was explored.

CASE II. G. N., a man, 30 years old, found himself in a capsizing boat at the dock. He grasped an overhanging log with his left hand while the right hand was caught in an oar nook of the boat. He remained in his position for fifteen minutes. With a diagnosis of "torn ligaments" the left shoulder was immobilized, notwithstanding the fact that the man's main complaint was a tingling and burning pain in the ulnar three fingers and in the palm of the hand. Only six months after the injury was a correct diagnosis made and an exploration of the brachial plexus followed.

CASE III. K. R., a 50 year old truck driver, fell off a high loaded truck to the pavement. He landed on the right shoulder while the head was forced to the left side. Because he was dazed for a moment he was treated for weeks for a concussion of the brain. Persistent complaints of pain in the right hand led to the diagnosis of a traction injury of the brachial plexus two months after the accident.

CASE IV. F. S., was a 62 year old laborer. A wooden case weighing about one hundred pounds fell against his right hand pinning it down to the platform of a truck. He was forced to remain in this position for some time

with the arm in abduction and external rotation. He suffered a great deal of pain in the hand and wrist, but this was attributed to "torn ligaments." The pain in the hand and later in the shoulder persisted and finally atrophy of the small hand muscles was noticed and the brachial plexus explored nine months later.

Common to all these cases were the increasing paresthesiae throughout the involved upper extremity. A picture of a causalgia of the brachial plexus was later superseded by motor weakness. In all cases suspected skeletal injuries monopolized the attention of the attending specialist until persistent complaints of pain, occasionally accompanied by atrophy of the small muscles of the hand, led to further consultations and to an exploration of the brachial plexus. By that time they all complained of intense burning and of a boring pain in the palm of the hand and the pulp of the fingertips. Then neurologic topography ceases to be accurate so that the physician, failing to reflect on the underlying pathologic physiology, regards these complaints as malingering and exaggeration.

Common to all cases were also the operative findings. The plexus was a mass of scar tissue. The individual cords were welded together in an irregularly shaped grey tough mass. They required free and tedious sharp dissection of the cords. The smaller nerve trunks were then isolated by means of infiltration with saline. Stubborn oozing of venous and arterial blood from the resected scar tissue made the operation still more difficult.

The operative results in all cases of traction paralysis were in inverse ratio to the length of time that elapsed from the accident to the time of operation. However, even in the greatly neglected cases the pain and paresthesiae were greatly ameliorated.

## DISCUSSION

GURTH PRETTY (Montreal, Canada): I believe that a discussion of this adequate paper of Dr. Kolodny requires a great deal of thought. I realized that, and also felt that I was being given this for being somewhat of a bad boy, not attending the meeting at Hot Springs last year.

True, as Dr. Kolodny has said, the literature is virtually filled with birth paralysis and birth trauma, but when it comes to the paralysis associated with accident surgery, there is very little written. Probably it may, as time goes on, get into the hands of the neurosurgeons who are rapidly encroaching on various branches of neurosurgery. Dr. Kolodny has brought forward several important and interesting facts regarding the anatomy of the bony structures associated with the brachial plexus. The spinal canal, the bony gutters for exit of spinal nerves with increased angulation as

compared to the infant, explain why we have so few cases of traction paralysis. Additional root damage is apparently prevented by snubbing of the roots by surrounding tissues and structures.

In Erb's paralysis root damage exists, while in our own experience among adults we have very few or comparatively few injuries of the traction type to the brachial plexus.

Is it possible that we miss them? No. Prior to ordering any medication or sedation, a careful examination of the extremity is made.

In fractures of the surgical and anatomical neck, there is a good deal of controversy about the treatment. Some will advise you to treat them with the arm alongside the body. Boëhler, on the other hand, puts them in complete abduction, extended and rotated. I agree with Boëhler as far as reduction of the fracture is concerned, but have experienced a good deal of trouble in mobilization of the shoulder. We have run into a certain number of wristdrop cases, although the wrist has been supported. I believe some of the bony spicules irritate the branches of the plexus, which has probably been partly influenced by hemorrhage into this inverse triangle which Dr. Kolodny describes.

The question is, whether or not some of those cases would not have shown signs of plexus traction in later stages, had we treated them by other methods.

It is true that when considering these plexus injuries, we have to study them from the point of view of injury to the roots, to the trunks, to the cords and the peripheral vessels. The reason we know so little about traction paralysis is that we have not, probably, taken the trouble or the interest to look into these cases, just the same as Codman, for instance, with his supraspinatus bursa.

Dr. Kolodny is to be congratulated upon such a scientific discussion of traction paralysis of the brachial plexus.

Clay Ray Murray (New York City): I want to compliment Dr. Kolodny on the very scholarly paper which he has presented. I think there is very frequent application of some of the points he brought out in the treatment of lesions far removed from the shoulder joint. I have noted on our own service, and have had similar information from other services, that in the application of body spicas for hip and spine cases, the arms are very commonly, with the patient under anesthesia, put above the patient's head.

We have had in the last twelve years five instances of partial paralysis of the biceps with cutaneous hypaesthesia following the distribution of the musculocutaneous nerve. This was bilateral in two instances. In these cases there was no lesion of the upper extremity at all, the patient having fractured the hip. The paralysis followed application of the body spica, and the only possible mechanism was raising the hands over the head and holding them there for quite some time. It is a common practice, and care

should be taken not to get the arms too high or hold them there for a long period of time in the application of body spica.

KELLOGG SPEED (Chicago, Ill.): This is a very important paper and not to be passed over too lightly. I think it has a practical bearing in the care of peripheral nerve injuries, and especially those resulting from trauma or gunshot, and the anatomical reasons given and exposed here explain some of the differences between the injuries of the nerve further peripherally from the spine than those high up in the brachial plexus. This funicular-like arrangement of the fascial covering in the cervical spaces, which encloses the cords of the plexus, may permit compression by bloody effusion, thus indicating the necessity for early release of pressure by operative procedure.

I have seen recently three injuries, fractures of the shoulder region, treated by the hanging arm cast, in which there has been some doubt in my mind whether the pull, weight and dragging of the cast did not have much to do with the paralysis which developed. The pull on muscles by traction is also a factor of practical importance.

ANATOLE KOLODNY (closing): I thank you very much, gentlemen. There is very little I can add.

# DIAGNOSIS AND TREATMENT OF POST-TRAUMATIC OSTEOPOROSIS*

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THE importance of post-traumatic osteoporosis as a major cause for the prolonged loss of function or severe aching pain, in or about multiarticular joints, which frequently follows in the wake of trivial as well as serious injury to an extremity, is not generally recognized. As a result, many innocent persons are unjustly accused of malingering or of being grossly unco-operative simply because their disability continues long after the effects of the original trauma have subsided, or after the fractured bones have had a chance to become firmly united in good position.

Post-traumatic osteoporosis is rare after trauma to the diaphysis of bones yet it is relatively common after injury, either with or without osseous fractures, to the periarticular or juxta-articular tissues. As early as 1901 both Sudeck[1] and Kienböck[2] studied this disease entity and showed that *inactivity* alone could not account for such a severe degree of trophic changes in bones; that these trophic changes came on much earlier than the changes which result from simple disuse; and that the reflex or trophic changes characteristic of post-traumatic osteoporosis usually came on while the extremity was still in active use. In 1926, Nobel and Hauser[3] reviewed the various theories about the causation and came to the conclusion that the only theory which could satisfactorily explain all of the pathologic physiology of bone in true osteoporosis was that the disturbance was a manifestation of a trophoneurosis as was originally suggested by Kienböck[2] in 1901.

## CLINICAL FORMS

In order to avoid all confusion with the atrophy of inactivity or disuse we shall only refer to the trophic changes in bone which follow trauma and which are associated with other vasomotor and trophic changes in the extremity, as the true post-traumatic osteoporosis. This disease entity is, therefore, characterized clinically by (a)

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partial loss of motor function of the extremity; (b) characteristic changes in the roentgenograms; (c) the constant co-existence of vasomotor and other trophic manifestations; and (d) the usual association with severe aching pain. The disturbances of the function are always more extensive than could be explained on the basis of the trauma alone, and the aching or visceral pain, when present, is greatly out of proportion with the local signs of injury to the tissues.

If we disregard the local effect of the trauma in these patients, we must still be impressed by the extensive loss of motor function and the obvious vasomotor manifestations which are present in such extremities. When the pain forms a characteristic part of the clinical picture, it has been our experience that such pain cannot be relieved by immobilization of the part; while the pain associated with simple trauma, fracture of one or more of the bones, or even tuberculous or pyogenic osteoarthritis, is definitely relieved by immobilization of the affected extremity.

Recently John Caldwell discovered four patients in his fracture clinic in whom all of the classical signs and the disability of true post-traumatic osteoporosis came on several weeks after injury to an extremity but without the aching pain. These patients will be the subject of a thorough study and report at a later date.

A common clinical form of acute osteoporosis is frequently seen after fractures of the bones of the wrist or ankle which have been properly reduced. After the removal of the bandage or cast at the end of two or three weeks, the extremity is found to be swollen and sometimes the skin is reddened. (Fig. 1.) Slight active or passive motion of the joint causes the patient great pain. Mechanotherapy, baking and massage usually make the pain more severe and the loss of function of the extremity continues to become worse. Diathermy gives only slight relief from pain and in our experience even intensive diathermy does not alter the course of the disturbance.

From the clinical point of view, the extension of the functional disturbance beyond the area of traumatization and accompanied by constant aching pain which is usually made worse by immobilization or proper physiotherapy, is pathognomonic of true post-traumatic osteoporosis. When acute osteoporosis was limited to the bones of the hands or feet, most of our patients have shown a hyperthermia of the skin over the affected parts.

The association of the subacute varieties of post-traumatic osteoporosis with cyanosis, subjective and objective sensations of coldness of the skin of the affected extremity, local edema and trophic disturb-

ances such as ulcerations, hyperkeratosis, atrophy of the skin and hypertrichosis and constant aching pain in the entire extremity, have been repeatedly pointed out by other observers. Congestion of the

FIG. 1. Characteristic gross changes in the soft tissues of the hand in post-traumatic osteoporosis during the acute or active phase of the disease process.

skin of the foot which is accentuated when the limb is placed in the pendant position, marked edema and a thinning of the skin with a disappearance of all of the surface markings giving it a "glossy" appearance is characteristic of the chronic phase of osteoporosis.

## ROENTGENOLOGIC ASPECTS

Two main forms of post-traumatic osteoporosis have been described as showing constant and characteristic changes in the roentgenograms. Sudeck[1] named these apparently distinct stages in the evolution of the disease the (a) acute form and (b) the chronic form.

The so-called *acute form* is characterized by a mottled appearance of the bones due to the irregular rarefied areas in the spongiosa of the bones. This mottling is usually most marked in the carpal and tarsal bones and in the heads of the metacarpal and metatarsal bones. In advanced cases the cortex of the small bones becomes very thin and the outline of the individual bones is frequently lost. The lamellae fade into one another and produce an ill-defined or homogeneous shadow in the roentgenogram.

In the so-called *chronic form* the trabeculae of the bones are very fine and sometimes difficult to recognize. The limits of the individual bones again become demonstrable, but there still remains a general

FIG. 2. The characteristic mottling of the bones of the left hand as shown in the roentgenogram during the acute or active phase of post-traumatic osteoporosis.

loss of mineral salts. The patchy areas of rarefaction have largely disappeared. The increased strength of the bone is due to a thickening of the longitudinal lamellae since the horizontal lamellae remain very thin.

In cases of post-traumatic osteoporosis of the short bones, especially the carpal and the tarsal bones, we recognize three stages in the evolution of the disease. These three stages are: (a) *the onset*, (*b*) *the height of the disease*, and (c) *the reorganization*.

We believe that each of these three stages presents characteristic roentgenologic changes. This evolution of the disease from the standpoint of the roentgenologic changes can best be portrayed as follows: In the period of onset there is a general mottled appearance of the

bones in the roentgenogram. (Fig. 2.) The outlines of the bones are still easily discernible. The rarefaction continues to become more marked and more extensive. The irregular areas of rarefaction soon

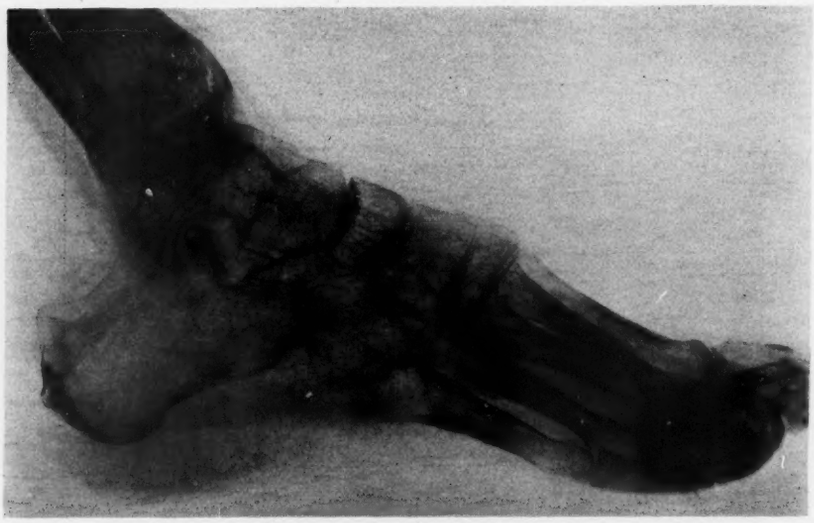

FIG. 3. Roentgenogram showing the characteristic changes in the structure of the small bones of the foot during the late or chronic phase of post-traumatic osteoporosis.

disappear and the bones become uniformly permeable to the roentgen rays. This stage of diffuse and marked decalcification marks the height of the disease.

The absorption of the bone seems to spread to the neighboring bones and thus involves the heads of the metacarpals or metatarsals, then the phalanges and finally the adjoining ends of the radius and ulna or the tibia and fibula, as the case may be. Marked thinning of the cortex of the bones takes place and longitudinal streaks appear in the thinned cortex. In the region of the carpal and tarsal bones this thinning of the cortex of the bones results in the disappearance of the limits of the bones and thus transforms the entire area into a homogenous mass which is very permeable to roentgen rays. It is at this stage that a diagnosis of tuberculous osteoarthritis is frequently made.

During the period of reconstruction there is a slow reappearance of the calcium in the bones. In most cases complete recalcification never takes place. Roentgenograms taken during this stage show that the limits of the small bones have again become visible and the longitudinal lamellae have become thickened. (Fig. 3.)

The duration of each of these stages is very variable. The factor of time seems to be of little importance. In general, however, the

first two stages are relatively rapid in their evolution, while the third or reconstructive stage is usually extremely slow. Complete anatomical restoration of the density of the bone, however, is not necessary for complete symptomatic relief or the return of normal function.

## CLINICAL EVOLUTION

It is commonly believed that post-traumatic osteoporosis is a selflimited disease and that after a few weeks or months, recalcification takes place without leaving any serious deformities. Sudeck[1] stated that favorable evolution is only occasionally seen, and it is *not* the usual end result of the disease entity. It has been our experience that after the disease has reached the climax or stage of almost complete decalcification, the process of recalcification may begin spontaneously, but years later, the roentgenograms may still show thinning of the cortex of the bones and thin lamellae containing irregular areas of recalcification. From these facts one might get the impression that the disease heals spontaneously since it is also well known that the vasomotor manifestations and pain may disappear without adequate treatment. In such cases, however, the *recovery of function of the extremity* requires many months and frequently during the stage of recalcification extensive fusion of the carpal or tarsal bones takes place. This ankylosis usually causes great economic loss to the patient. Undoubtedly many of the mild forms of post-traumatic osteoporosis do heal spontaneously and give no permanent disturbance of function; therefore, one must be careful not to assume that some particular form of therapy used in any one patient is a true remedy for the disease entity under all circumstances.

## TREATMENT

The treatment of post-traumatic osteoporosis has, until recently, been symptomatic and preventative rather than curative in nature. Sudeck[1] recommended minimum immobilization and then active movement in most of his cases. In 1926, Nobel and Hauser[3] recommended heat to the point of tolerance either in the form of radiant heat or paraffin baths. They also advised massage and voluntary motion of the joints in spite of a little pain, *but they emphasized that forceful manipulation under anesthesia was definitely contraindicated.* Any form of fixation with plaster-of-Paris casts or orthopedic apparatus causes increased pain to the patient. Delorme[4] recommended treatment by thyroid and parathyroid extracts and Pech[5] advised heliotherapy.

In 1924, Clarence Heyman[7] suggested periarterial sympathectomy for the treatment of painful osteoporosis. The relief of pain and the restoration of function promptly followed this operation.

The true function of the longitudinally coursing fibers in the adventitia of large arteries has never been actually demonstrated, yet there is little doubt in the minds of students of this problem that removal of the adventitia of the main arteries of the extremity does bring about definite changes in the nutrition in the periphery of that limb. It is our belief that these fibers in the adventitia of the arteries have a definite trophic function, and it is the interruption of abnormal trophic reflexes that course along the fibers in the adventitia that accounts for the striking beneficial results obtained after periarterial sympathectomy in patients with post-traumatic painful osteoporosis.[8,9,10] We do not recommend periarterial sympathectomy as treatment for the true vasomotor instability of Raynaud's syndrome.

In 1934, Fraser Gurd[6] advised the use of "walking plaster casts" and physiotherapy, and reported satisfactory clinical improvement.

The recent (1938) recommendation of roentgenotherapy for acute painful osteoporosis by Mumford,[11] of Indianapolis, has interested us a great deal and during the past year Dr. Jack E. Singer, of the Department of Roentgenology of the Cincinnati General Hospital, has treated four patients with acute painful osteoporosis of the post-traumatic type, and John Caldwell has had under his observation two other patients who had received adequate roentgen-ray therapy for osteoporosis.

## SUMMARY OF CASES

During the eight years from June, 1932, to June, 1940, we studied eighty-four patients with post-traumatic osteoporosis in the out-patient clinics of the Cincinnati General Hospital.

Thirty-four of these patients presented the signs and symptoms of the *acute painful variety* of post-traumatic osteoporosis and were treated by periarterial sympathectomy. All of these patients who were subjected to periarterial sympathectomy had relief of the severe aching pain within twenty-four hours after the operation with disappearance of the edema and functional disturbance within a few days. These patients were able to resume their work within an average time of approximately three months. Complete return of function in the control group treated by means of physical therapy together with other conservative measures took more than nine months.

We have found that operations upon the autonomic nervous system offer a rational and effective surgical treatment for this disease entity *if the operation can be performed during the acute phases of the disease process*. The relief of pain and the sudden disappearance of the functional impairment has frequently been almost immediate and the undesirable sequellae of this disease have been prevented in the patients with acute osteoporosis whom we have studied. In previously reported studies[8] we found that the *patients in whom the symptoms were present for more than nine months received relatively little benefit from periarterial sympathectomy*.

Four of the patients of this series were treated by roentgenotherapy according to the method of Mumford. In all cases there was relief of pain within one week after the radiation therapy was started. Subsequent follow up studies upon these patients, however, reveal that the functional disturbance does not show corresponding improvement. From our own studies of this small group of patients we get the impression that the period of disability is not greatly shortened by the roentgenotherapy but the prompt relief of pain is a great comfort to the patient, and it does permit the partial use of the extremity earlier in the convalescent period even though the degree of disability remains high.

The remaining forty-six patients came under our observation during the *subacute or chronic phases* of the evolution of the disease and were, therefore, given only intensive physiotherapy consisting of massage, functional stimulation, infra-red and ultra-violet radiation and hydrotherapy. Analysis of these patients showed that the course of the disease was only slightly shortened and the unfavorable sequellae were about as frequent as when the process was left untreated.

## CONCLUSIONS

1. Post-traumatic osteoporosis is a disease entity with characteristic roentgenological changes in the three main stages in the evolution of the disease.

2. Post-traumatic osteoporosis which is left untreated may result in ankylosis of one or more of the joints in the region of the trophic disturbance in the short bones.

3. Operations upon the sympathetic nervous system offer a rational and effective surgical treatment for this disease entity.

4. Cases of post-traumatic osteoporosis treated by sympathectomy during the *active phases* of the disease respond quickly and the undesirable sequelae of the disease are prevented.

5. Periarterial sympathectomy is usually sufficient for cases of post-traumatic osteoporosis which is limited to the distal part of the extremities.

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## DISCUSSION

John A. Caldwell (Cincinnati, Ohio): It has been my privilege to be associated with Dr. Herrmann in this work principally as a supplier of material. I was infected with his enthusiasm from the first and since then we have gone along together.

It is not possible, even if it were necessary, to add anything more to what he has said, but probably to emphasize a little bit some of the outstanding features which make it important to persons who are dealing with the surgery of trauma.

First, I should like to call attention to the fact that he has mentioned that it is very frequently associated with trivial injuries. Quite a number were not associated with any fracture at all, and one of the things that we have begun to regard as almost symptomatic of the condition is that it is very likely to develop in fractures that have been well reduced.

The Colles' fracture, impacted in such good position that the parts require little manipulation, is quite prone to be followed by osteoporosis; while the badly comminuted and smashed os calcis in severe injuries of the foot is frequently found exempt from this condition.

Great injustice is done these patients by lack of recognition of this condition. I can best show that by reciting a recent case of a young man who fell down an elevator shaft and sustained a Pott's fracture which was easily and

well reduced under local anesthesia. He had excruciating pain all night to such an extent that he required anodynes. That continued for several days, so that I felt it was necessary to inspect, and on taking off the cast, found it was perfect. There was no pressure sore, nothing at all to account for this condition, and a second cast was applied and his pain continued. His foot remained painful for the ten days he stayed in the hospital.

At that time he still said it was painful and I arrived at the almost inevitable diagnosis of a functional condition. I interviewed first his employer and he gave me a very definitely warm earful. The patient was a valuable employee and compensation was not a question. They were anxious to do everything for him.

At the end of two weeks, on removing his cast and taking contrasting plates of the two ankles, we could see what we thought was very slight change in the affected foot.

Without further detail I can say that this patient went on to a complete osteoporosis of a very aggravated degree. He would not submit to a sympathectomy. He received *x*-ray treatment, and it has given him definite subjective relief, but it has not been followed by corresponding improvement in the bone picture.

The principal thing in our experience, to bear in mind is that this is a real, definite, pathological thing which must not be mistaken for a neurosis. This atrophy is entirely different from the atrophy of disuse, in that it appears very much more promptly, develops more rapidly, and is not a diffuse demineralization, but the spotty, rotten wood appearance, which is quite characteristic to anyone who is familiar with it.

THOMAS PETERSON (Boston, Mass.): I should like to ask whether Dr. Herrmann believes the use of novocain has anything to do with the production of osteoporosis, and also I should like to know whether he believes age has anything to do with its production.

JOHN A. CALDWELL (Cincinnati, Ohio): May I have a minute to speak about novocain? I can answer very definitely that novocain has nothing to do with osteoporosis, because a great many of these patients have not had fractures at all, so that they have had no treatment; others have had fractures with so little displacement that they require no manipulation. We have had several cases in which the injury was at a distance from the development of the osteoporosis, for instance, a fracture of the knee joint, and the patient had an osteoporosis of the foot and ankle.

NELSON J. HOWARD (San Francisco, Calif.): I should like to ask whether the authors have had experience with the sympathetic block of the lumbar sympathetic or thoracic system, for the reason that the sympathetic is segmental, and the periarterial sympathetic, too, and I have wondered what the effects would be from the more complete block.

LOUIS G. HERRMANN (closing): I have no positive information concerning the possible rôle which local injections of novocain, in and about joints,

have upon the productions of osteoporosis. It is not uncommon to see osteoporosis follow relatively trivial injuries to the periarticular tissues, but I would be of the opinion that blocking the sensory nerve endings in and about the joints would tend to reduce the chances for the development of true osteoporosis.

Osteoporosis occurs mostly in the third, fourth and fifth decades of life and it is rarely observed in children.

Extensive structural changes in the peripheral arteries which occur in the sixth and seventh decades of life may give rise to osseous changes, visceral pain, local vascular and trophic changes and produce a syndrome which is not unlike this post-traumatic type of osteoporosis.

In regard to Dr. Howard's question, I might say that it is possible to interrupt these pathways for abnormal reflexes by blocking the regional sympathetic chains. Such a procedure, however, requires considerable special training and skill and I do not believe should be routinely done by the average general surgeon. We are convinced that periarterial sympathectomy is a simpler procedure and a more effective way of assuring a complete block of the abnormal reflexes.

Recent clinical studies have given us the information that the major pathways of these neurotrophic fibers are in the adventitia of large arteries or are at least segmentally distributed to the periarterial network from the peripheral somatic nerves. These fibers do not course through the regional sympathetic chains or ganglia and this, we believe, accounts for the failure of improvement of post-traumatic osteoporosis after the surgical removal of the regional sympathetic ganglia (sympathectomy) or the interruption of the rami to the ganglia (ramisection), while striking improvement usually follows the denudation of the major artery to the affected part. In the present state of our knowledge we do not recommend operations upon the sympathetic ganglionated cords in the management of post-traumatic osteoporosis.

It has been a real pleasure to have the opportunity of discussing this problem before you and I hope that I have emphasized the importance of this troublesome complication which follows so frequently in the wake of traumatization of an extremity.

# THE POSSIBLE ETIOLOGIC RELATIONSHIP BETWEEN A SINGLE TRAUMA AND MALIGNANT TUMOR

HERBERT H. DAVIS, M.D.
OMAHA, NEBRASKA

IT is generally agreed that chronic irritation or frequently repeated mild trauma may be the exciting cause of a malignant tumor in a susceptible individual. This discussion does not consider the above causes, but refers only to the question of a single trauma as a possible cause of a malignant tumor. Patients often consult their physicians following an injury with the fear that this may cause the development of cancer. The medicolegal aspect of the question arises even more frequently. In connection with the Workmen's Compensation Law, the relationship of trauma to neoplastic lesions is becoming increasingly important.

Recently I testified in such a case. The main facts were as follows:

A laborer, age 48, in the employ of the State of Nebraska, while driving a car, struck the left side of his jaw against the side of his car when it hit a bump. Three weeks later he noticed a swelling below the angle of the mandible. The tumor continued to enlarge, and a month after the injury he noticed a weakness of the muscles of the left side of his face. Soon after this pain developed in the region of the mass and extended upward behind the left ear and into the left temple.

Examination four months after the injury disclosed a large cancerous mass in the left superior deep cervical lymph nodes. Biopsy from the mass showed it to be a metastatic adenocarcinoma. The patient later consulted a so-called cancer specialist who used an arsenic paste on the neck region which caused a very extensive slough. Ten months after the accident he died of the carcinoma.

His family brought legal action against the State of Nebraska, claiming that the injury sustained while he was working for the state resulted in the carcinoma which caused his death.

The testimony was very interesting. The plaintiff's physicians testified that the injury of the deceased, which was definitely described as occurring up over the cheek and mandible rather than over the neck, was the cause of the cancer. When asked where the primary growth had occurred, they stated in the mouth, and one even stated that the carcinoma might have arisen in the bone of the mandible. The State showed that no sign of a

primary growth had appeared in the injured region; that the blow had not been in the area of the neck, where the metastatic carcinoma was; and also that the type of cancer found microscopically would not have arisen in squamous epithelium, which is the only type of epithelium in the area struck. Unfortunately, no primary growth had ever been located and no necropsy had been done. In spite of this testimony, the verdict was for the plaintiff.

It is realized that a definite scientific opinion cannot always be given regarding the relation of a single trauma to the subsequent development of cancer. Often, however, a definite opinion may be given. In the above case, for example, scientific evidence should show that no tumor arose at the site of injury, and that epithelium at the site of injury was not the type for the development of an adenocarcinoma. Therefore, the carcinoma could not be caused by the injury to the jaw, and the verdict was scientifically incorrect. A large number of such cases arise under workmen's compensation laws. Too large a number are decided incorrectly by the courts.

## HISTORICAL

Askanazy[1] stated that the literature dealing with the subject was only a "collection of anecdotes," and that it contained many highly uncritical studies. Those interested in this question are referred to an excellent review of the literature by Ophuls[2] in 1921 and Knox[3] in 1929, and the quite thorough discussion by Ewing[4] in 1935.

The relationship of trauma to cancer was discussed by Lowenthal[5] of Bollinger's Laboratory, at Munich, in 1895. From 800 cases in the Pathological Institute at Munich from 1870 to 1895 there was a history of acute trauma in 358. So little critical analysis was made that this article probably proved nothing. Schimmelbusch[6] felt that conclusions based upon compilations of case histories were absolutely unscientific and not of great value. He stated that scientific matters could not be based upon untrustworthy and unreliable evidence, and that on this subject all the evidence was essentially unreliable.

In 1898, Coley[7] studied the role of injury in the development of sarcoma. In 170 cases there was a history of trauma in forty-six (27 per cent). These cases, again, were not thoroughly studied.

Owing to the growing interest in this subject, it was thoroughly discussed at the Second International Conference on Cancer at Paris in 1910. At this time Theim[8] laid down five postulates which had to be fulfilled before trauma should be considered the cause for the subsequent development of cancer. These were as follows:

1. The occurrence of the trauma must be proved.

2. The trauma must have been severe enough to be effective.

3. The growth must appear at the place likely to have been injured by the trauma.

4. It must be reasonably certain that the traumatized part was normal before the accident.

5. The time elapsing between the trauma and the appearance of the tumor must agree with our scientific experience on the rapidity of the development of the particular kind of tumor under consideration. It must not be less than a few weeks or over two years unless there are symptoms which bridge over the intervening period.

Of these rules, No. 4, regarding the certainty that the traumatized part was normal before the accident, is the hardest to prove.

Lowenstein,[9] in 1910, in a long monograph on the subject, analyzed from the literature 261 cases of malignant tumors—seven from Heidelburg and three from Frankfurt—according to the histories, which were considered traumatic in origin. This paper was superior to previous articles inasmuch as an attempt was made to apply critical standards to the histories, and the author appreciated the need of scientific methods in making conclusions. He presented tables giving clearly the lapse of time between the injury and the development of the tumor. He included only those in which the injury was described as being at the exact site of the subsequent tumor.

Brosch[10] believed that a single trauma could not cause a tumor, but that the early productive and reparative changes observed in scars were essential forerunners of the neoplastic process. This fact accounted for the inability of experimenting pathologists to produce tumors in normal tissues. Goebel[11] also stated that a single injury never caused a malignant tumor, but that chronic irritation, repeated injuries and scar tissue might do so. Oberndorfer,[12] too, believed that some underlying predisposition must be present in addition to trauma.

Virchow,[13] while admitting the fact that the influence of traumas could not be dogmatically denied, stated that there must be some as yet unknown predisposing factor in the patient, and also that the trauma must have been implanted on pathological tissues. Ribbert[14] opposed the theory that a trauma could cause a tumor, but admitted that the possibility must be conceded. He had never seen a clearly demonstrated case.

Mock and Ellis[15] reviewed the literature. They quoted Bloodgood[16] as saying in an address before the Ninth Annual Convention

of the International Association of Industrial Accident Boards and Commissions, at Baltimore, October 11, 1922: "In my own group of now 1,000 bone tumors, of which perhaps 400 are sarcoma, I have but two cases in which directly after the injury an *x*-ray was taken showing a negative bone." Mock and Ellis reported nine cases which they believed fulfilled the postulates. Of these, two were metastatic tumors, one a teratoma of the testis following several injuries, and one a sarcoma of the bone in which the sarcoma was likely existing before the injury. In conclusion they said: "There is no justification for assigning trauma as the etiologic factor in any particular case, unless this can be proved with scientific accuracy. In the great majority of cases commonly reported as the result of trauma, such an etiology cannot be scientifically established."

McKendrick[17] asserted that there is no authentic case quoted in medical literature in which it can be proved beyond a doubt that fracture caused sarcoma.

Only a few of the many authorities have been quoted. However, more of such reports seem unnecessary, as they are all very indefinite and not based upon scientific data.

## WAR RECORDS

A group of authorities have studied records of the first World War in regard to this matter. The general impression was that no greater percentage of tumors could be observed in war veterans than in civilians. In the period since the war no increase in the incidence of tumors has been found. The age of the soldiers was the age of people ordinarily suffering from sarcoma. In studying a large number from the Western Front, Pick[18] was able to find only two cases of sarcoma which he could even suspect of having arisen from war injuries. In the large number of cases studied, this would be no more than would be found in any similar age group of people.

The French Association for the Study of Cancer investigated this subject in 1918 in the light of experience obtained during the war. Some of the leading pathologists and clinicians discussed the problem and practically all, with the exception of Berard,[19] thought that trauma had nothing to do with the appearance of a tumor. Berard had previously given his opinion at the Paris Conference in 1910.

Lowenstein, in his military service from 1889 to 1917, found no increase in the percentage of sarcoma. In the Prussian Army, from which he obtained his figures, he found only one case of post-traumatic tumor in 15,000 cases.

Forgue[20] showed that the regional distribution and age distribution in 536 cases of cancer were practically proportional to the like distribution in the male population not in the service.

Von Hansemann[21] stated that not only was there no increase in the number of tumors following the war, but also no new types appeared.

### THE ELEMENT OF CHANCE

From the records of the New York State Industrial Compensation Bureau, Lewy[22] found thirty-seven cases of malignant tumors among 26,389 injured persons. In few of these cases could the traumatic origin be established as reasonable. This ratio was about 1 to 700, or approximately that of the general population at the age of fifty.

Ewing stated that French medicolegal experts reported the occurrence of as low as five or six traumatic tumors among 100,000 injuries.

Knox estimated that, as the average life of a patient with cancer had been computed to be about two years, there should be in the population as a whole some 250 persons in each 100,000 who had cancer in some stage, in addition to those who were to die within the year. In other words, besides those who died of the disease, one person in 400 of the whole population probably had cancer in some stage of development. As sarcoma formed about one-tenth of the total of malignant tumors, 1 person in 4,000 might have an unrecognized sarcoma. He stated that the possibility of a trauma calling attention to a tumor already present must be recognized in any study of the relationship between injury and the production of a sarcoma.

Williams[23] showed that men were more subject than women to trauma, especially to the more severe injuries such as fractures, sprains, and dislocations. In his material, however, men had fewer cases of cancer than women, a proportion of 1 to 1.7. In commenting on this, Knox stated that the difference in these figures was due to the frequency of cancer occurring in internal organs, which are rarely traumatized. Therefore, it is not as effective an argument as first appears.

### ANIMAL EXPERIMENTS

Experimental cancer is now being produced by many agents but always under quite specific conditions not related to trauma. Knox and Ewing have both stated that attempts to produce tumor by trauma experimentally have all failed.

Most animal experiments on the subject of trauma and malignant tumors concern the effect of trauma upon an already existing malignant tumor rather than the role of trauma as cause of the tumor. In this latter type of experiment Lubarsch[24] concluded that trauma could be accepted as a factor in growth if (a) violence was severe, localized, and long continued at the same point at which the tumor later appeared; and (b) the histologic structure of such a tumor made it reasonable that the growth was due to injury.

In a series of 12,000 autopsies on the bodies of mice dying at all ages either from natural causes or, in a relatively small number, from accidents, Slye[25] found only eighty-seven mice with neoplasms meeting all the criteria of sarcoma. In at least eleven of these, sarcoma arose at the site of previous injury. She had no knowledge of how many of the other seventy-six had received injury at the point at which they subsequently developed sarcoma; although injuries to mice are numerous, especially among the males, which often receive wounds in fighting. She found that the influence of heredity in determining the development of sarcoma at the site of old wounds was especially noticeable and important in this series.

## CASE HISTORIES

In the literature many cases have been reported in which a single trauma has been thought to be the cause of cancer. A large number of these reports have referred to sarcoma, especially to osteogenic sarcoma. Meyerding[26] at a conference at Memorial Hospital on the treatment of bone sarcoma reported 100 cases of osteogenic sarcoma. Of this group, he found a history of trauma definitely positive in forty-two cases, definitely negative in eight and not stated in fifty. In his discussion he stated, "I think it is significant that 50 per cent of these patients were in the most active period of life, eleven to thirty years of age, and that 75 per cent of the tumors developed at sites of common injury. There must exist some unknown general condition among these patients which allows cells to become malignant following trauma as an exciting cause."

In this same discussion Simmons[27] stated, "Osteogenic sarcoma is usually seen in a healthy individual. A history of trauma followed by the usual symptoms of pain and swelling which subside, but which are followed after a period of from four to twelve weeks by a recurrence of pain is very suggestive of a primary malignant bone tumor."

Collins[28] analyzed fifty-one cases of malignancy of the testis. He found about thirty-five, or 68.6 per cent, gave histories of prior

trauma. However, the casual relationship was not adequately discussed. In many of them the malignancy did not arise until years after the injury.

Leighton and Schmidtke[29] collected from the literature a group of cases of malignancy with trauma as a possible cause. To these they added a brief outline of case histories of seventy-four similar cases from the Barnard Free Skin and Cancer Hospital in St. Louis. A large number of their cases were cancer of the skin.

Rixford[30] considered trauma the cause of cancer of the breast in the following case:

> A boy, age 17, while running fell on a tree stump, striking his right breast. Seven days later, because of pain, swelling and soreness, he consulted a physician, who found the breast markedly swollen, red, hard and discolored. The skin was abraded and the nipple and aerola injured. His temperature was 101°F. Axillary nodes were enlarged. Within a few weeks the breast became normal, except for a small lump directly beneath the nipple. Eight weeks after the injury the swelling was increased. Five months after the accident, mastectomy was done, but no microscopic examination made. The patient died four years later with widespread lymphatic metastases.

Because of the importance of the case the records were submitted to Dr. Ewing, who reported, "There is no escaping from the conclusion that in all probability, if not a certainty, the boy presented a genuine case of traumatic mammary cancer."

On the basis of case histories alone, it is often impossible to prove either that the single trauma did or did not cause development of a malignant tumor. The possibility is quite definitely ruled out unless details of the case conform with Theim's postulates.

## CONCLUSIONS

1. A single injury to previously healthy tissue has never been definitely proved to cause cancer.

2. Nobody has succeeded in experimentally producing a series of malignant tumors by trauma.

3. The element of chance would account for the incidence of trauma in a fair number of cases in which cancer developed. The general impression of those who have studied large numbers of injured people is that they show no increase of cancer over those who have not had single injuries.

4. On the other hand, in individual patients, it may not be possible to disprove absolutely the etiological relationship. Even to

consider trauma as a cause, the following postulates must be fulfilled: (1) The authenticity of the trauma; (2) the adequacy of the trauma; (3) the origin of the tumor at the location of the injury; (4) the previous integrity of the injured part; (5) a reasonable time limit between the injury and the appearance of the tumor; and (6) the positive diagnosis of the presence and nature of the tumor.

5. Trauma reveals many malignant tumors. Whether it can actually cause a malignant tumor is an unsettled point.

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## DISCUSSION

Arthur R. Metz (Chicago, Ill.): In considering the possible etiological relationship between a single trauma and malignant tumor, we should keep in mind three generally accepted facts:

1. The cause of malignancy is unknown.

2. It has been impossible to produce experimentally malignant conditions at will.

3. We have no way of knowing when a malignant condition actually begins.

As a rule malignant tumors are not recognized until a palpable mass occurs or pain develops. Any trauma occurring to the patient during this unknown silent period may be wrongly accused as being the exciting cause.

Some recent writers on this subject, such as Reed and Emerson, Indianapolis, in 1938, made the following statement: "That cancer may result from the single trauma is emphatically denied although this has been claimed for all types of malignant tumors. We do not know the cause of cancers, hence our conviction that no malignant growth is ever the result of a single trauma, is based on indirect and unscientific evidence."

Richard J. Behan, in his book "Relation of Trauma to New Growths," in 1939, wrote as follows:

"Heredity, constitutional predisposition, and other contributory causes are generally so associated in its origin that the possibility of a single indispensable agent acting as a sole exciting cause is universally doubted."

The same author quotes Knox as follows:

"It has never been possible to produce a malignant growth experimentally in animals by a single trauma. We must be cautious of the role which trauma plays in the production of cancer, for trauma because of its dramatic appeal and easily conceivable possibilities may assume a disproportionate prominence among the many influences which are necessary in the causation of a malignant growth."

Every surgeon at time of operation cuts tissues with a scalpel and scissors, applies many hemostats to epithelium and connective tissue, clamps blood vessels and ties catgut and silk ligatures, so that in every operative wound there is a certain amount of necessary trauma. To my knowledge I have never heard any surgeon with an extensive experience admit that his operation was a cause of a carcinoma or sarcoma. I have never heard a surgeon suggesting or considering the possibility of a malignancy developing in a wound unless he was operating on a malignant condition that he knew was present at the time of operation.

In following the injury reports of a large railroad during the past twenty-five years, where the number of accidents have totaled over 175,000, there has never been, to the knowledge of the Claim or Surgical Departments a claim made for an injury producing or aggravating a malignancy. In this series of injuries, fractures were present in about 10 per cent of the cases.

In another series of injuries totaling 47,000 among employees of railroads and insurance cases, there has never been, to my knowledge, a case of malignancy developed or has there been a claim made.

In another series of 6,000 fractures during the last twenty years, which have been confirmed by *x*-ray and followed through to recovery, there has been no case complicated by malignancy.

It is interesting to note that some of the areas of the body that are exposed to the greatest amount of trauma, namely, the soles of the feet, the

palms of the hands and the bridge of the nose, where the weight of glasses is constantly pressing, we almost never see a malignancy develop in these areas.

It would seem logical to conclude that if a single trauma could produce a malignancy, it would become a recognized complication of operative wounds. At present, surgeons who have a vast operative experience are not reporting or considering malignancy as a complication in general surgery when the case is not primarily of a malignant character.

In the large volume of negative evidence that can be produced, it would seem conclusive that a single trauma could not produce malignancy, and that this Association could best devote its efforts to aid further in the research on malignancy and help in seeking the true cause. Until the true cause is actually found, and malignancy can be produced experimentally, we should not hesitate to admit that we do not know the cause of cancer.

JOHN R. NILSSON (Omaha, Nebr.): Before coming here, I had an opportunity to read over Dr. Davis' paper and also writings of others on the same subject, and I think Dr. Davis answered the question in his conclusions by saying that it is still a controversial question.

Many of the German and French writers still hold to the fact that trauma does cause cancer. Others are equally positive that it does not, and all those who say it does not give as their two main reasons: First, that we have thousands of cases of injury on record without a carcinoma following. Second, they refer to the work of Maude Slye with her three strains of mice, one strain in which there is no predisposition to cancer, one with predisposition to skin cancer and one with predisposition to lung cancer.

When these three strains are subjected to trauma of the skin, only those predisposed to skin cancer developed cancer, and always at the site of injury.

I am not here to tell you that trauma causes cancer, but it is a question that comes up with us, and while I cannot talk in as large figures as Dr. Metz, 200,000—I am with a different railroad (The Union Pacific), and we do not have quite as many accidents—I have had cases in which trauma has apparently resulted in new growth, and I am going to take a few minutes to review these cases:

CASE 1. H. G., age 47, was struck on the side of the leg, lower third of the femur, by the side rod of an engine. He had a bruised spot there, swelling and discoloration. He did not pay much attention to it. Three or four months later he noticed that the swelling had not disappeared. There was apparently a growth. He went along and continued his work as if it did not cause him much trouble. He went a few months longer and then consulted a doctor, and in one year's time the swelling had not disappeared.

They did a biopsy and found a fibrosarcoma. He was treated with a deep *x*-ray, very extensively. When I saw him three years later he had a large ulcerating area on the outer lower third of his femur, caused by *x*-ray. It

went from bad to worse. Finally, he was operated upon in one of the large clinics of the country. They did an amputation and following that he had metastases to the groin and the glands in his pelvis, and in less than a year from the time he was operated upon he died of carsarcoma.

CASE II. A. M., age 52, was struck in the elbow in April. The following August he had a tumor. He had a bruised spot there and when we examined it, we simply thought it was probably a blood clot, an organized blood clot. I removed it and it was in the fascia, not connected with the bone, and that proved to be a sarcoma. That was in August. In November, four months later, I did exactly the same thing. He had another sarcoma, a recurrence in the same place.

CASE III. The patient, age 66, came to us in March and said four months before, or for the past four months he had been having pain in the lower third of his right leg. This man was apparently in perfect health and he said, going into the history, that he had a habit of showing how strong he was. He would take a soft flat iron poker and strike himself across the leg. Whether that had anything to do with it or not, I do not know but his leg was amputated. It had an osteosarcoma and he lived less than a year after his amputation.

CASE IV. A farmhand, age 18½ years, while riding a tractor bruised the upper third of the lower right leg, the proximal end of the fibula. There was the usual swelling and discoloration. He did not pay much attention to it. When it pained him, he consulted a doctor and he was told that he had a charleyhorse. That was in June. In July the pain became worse so he consulted a surgeon. A biopsy was done and it was found that this was a sarcoma. The leg was amputated and he died within one year from the time of operation.

The history in the cases enumerated gave us no clue as to any pre-existing, predisposition to cancer.

PHILIP H. KREUSCHER (Chicago, Ill.): I think such a fine paper as this should be reprinted and sent to the industrial commissioners all over the United States and Canada.

While I was connected with the Industrial Commission of the State of Illinois, several cases came under my observation:

One was a young woman about thirty years of age, who was carrying a heavy basket on her shoulder. The basket slipped and she sustained a rather severe abrasion over the spine of the scapula. Two and one-half months later a tumor developed in that area. Biopsy showed this to be a sarcoma and the entire scapula was removed. In spite of this radical and rather prompt surgery the patient died of generalized sarcomatosis.

Another case was that of a young man who was struck on the shin by the door of his automobile. In about two months a tumor developed over that area, which was about four inches below the knee joint. Biopsy showed sarcoma and after several days the leg was amputated. The patient died within four months.

I think it is impossible to produce artificially a sarcoma by repeated trauma, but ever so often a tumor develops following trauma. One must be able to state his opinion in his testimony before the commissioners and the courts. It is difficult to convince a judge and jury that not all sarcomas or malignant growths are preceded by trauma. I believe that it is a step in the right direction to educate not only ourselves as surgeons but also those who rule and have the right to rule and from whose decision there is no recourse.

HERBERT H. DAVIS (closing): I wish to thank the discussers.

In regard to individual case histories, it is very easy to collect large numbers of cases that look as if a malignant tumor was caused by an injury. In taking a history of any individual, irrespective of the complaint, and asking whether he bumped himself or received any injury, almost everyone has. Therefore, considering these cases, we have to say that trauma is so frequent that the coincidence of the two coming together cannot be ruled out. On the other hand, we cannot make a definite statement that trauma cannot cause an injury. It depends upon whom the burden of proof lies. We can say definitely, however, that any case even to be considered as having been caused by trauma, must answer the postulates I gave in my conclusions.

# THE PRESERVATION OF TENDON FUNCTION BY THE USE OF SKIN FLAPS

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INJURIES to the hands, which cause extensive loss of soft parts exposing the tendons, present problems whose solution will determine the amount of ultimate function. The preservation of the tendons will determine the functional result. Exposed tendons will gradually slough unless they are covered and will not function unless they are covered with fat. In cases of severe injury in which there has been a loss of overlying tissue, a flap must be used to carry the fat and keep it viable until it secures its circulation from its new site.

The following cases are reported to illustrate the various methods which can be employed in the treatment of these patients. Three of these cases were industrial accidents and the fourth was an accident which could well be industrial.

## CASE REPORTS

CASE 1. A white male, age 18, was admitted to the hospital for a crushing injury to his right hand which had been caught in a press.

Three weeks after admission he was referred to us to determine whether the hand should be amputated. (Fig. 1.) The skin had sloughed from the dorsal surface of the wrist and the palm. The fingers were devoid of skin with the exception of the little finger which appeared to be normal except for a flexion deformity at the distal joint due to a fracture of the joint. The ends of the other fingers and thumb from the second joint were necrotic and separating. The dorsal surface of the hand showed exposed tendons which were sloughing. There was some skin near the base of the thumb and at the commissure between the thumb and the index finger. He could move the fingers and it was deemed worthwhile to save the hand if that amount of function could be preserved.

The patient was treated for a week with Dakin's solution to clean the infection and then an Ollier-Thiersch graft was taken from the thigh and placed on the palmar surface. A gauntlet flap was then raised on the left abdomen and the hand sutured to the flap which covered the exposed tendons on the dorsal surface. The abdominal skin beneath was approximated with silkworm gut sutures. (Fig. 2.) The necrotic ends of the thumb, index and ring fingers were removed. The end of the middle finger was not

removed because it had not demarcated sufficiently. A dressing of silver foil was placed against the graft and the hand was immobilized with adhesive straps. The healing was uneventful and three weeks later the ends of the

FIG. 1. Case 1. Degloved hand after a pressure injury. The skin is lost from the palm but the fat remains. The skin with the underlying tissue is lost from the dorsal surface exposing the tendons. The ends of the fingers with the exception of the little finger are sloughing.

flaps were severed under local anesthesia. (Figs. 3A and B.) The graft had taken satisfactorily on the palm. A few days later, after the graft had dried out, the margins of the flap were sutured in on the sides of the hand. (Figs. 3C and D.) The patient was discharged from the hospital two weeks later. He had some function but the hand was stiff. Massage was instituted and function greatly improved. A year later the scar was relaxed in the palm by spliting the scar and grafting. The patient can now use a typewriter and

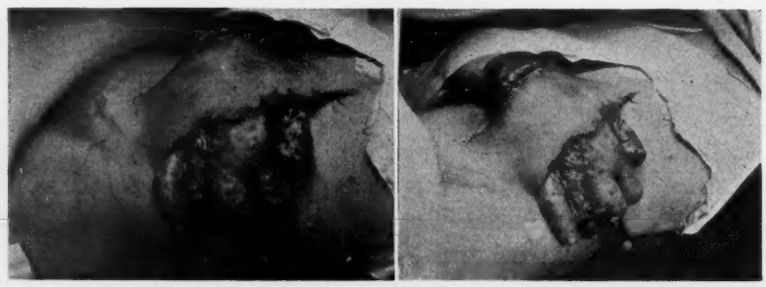

FIG. 2. Case 1. The hand has been placed under a gauntlet flap covering the exposed tendons. The necrotic ends of the fingers which had demarcated have been removed. The palm of the hand has been covered with an Ollier-Thiersch graft.

use the hand freely. The only handicap is the shortness of the fingers. This will be corrected by relaxing the commissures and shifting the flap. (Fig. 4.)

*Comment.* The treatment should have been started sooner. The time lost in covering the tendons permitted them to become adherent so that function was more difficult to secure. The secondary grafting may have been avoided. The function this patient has well justifies preserving the hand.

CASE II. A white male, age 19, was admitted to the hospital for treatment of a crushing injury to the hand, which had been caught in a press. The distal ends of the little and ring fingers were crushed and were ampu-

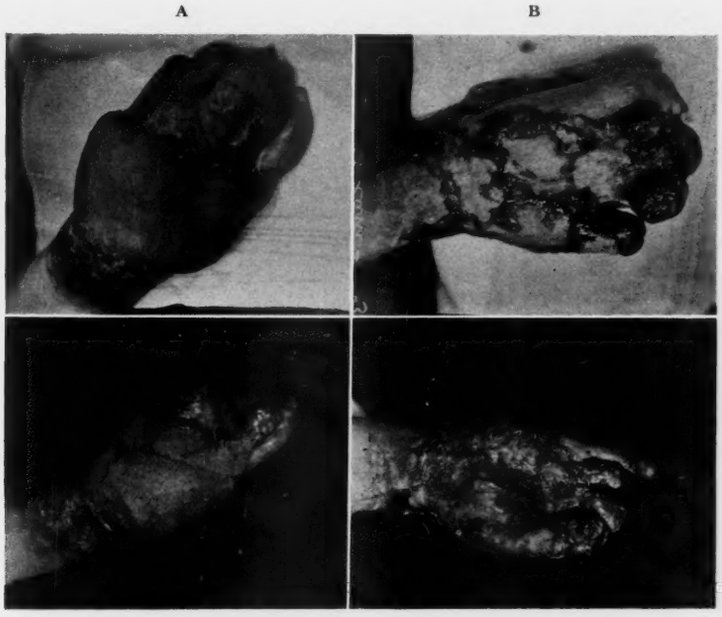


FIG. 3. Case 1. The flap had been cut from the abdomen three weeks after it had been attached. Note the margins of the flap, B. The graft had taken fairly well covering most of the palm. C, dorsal surface of the hand after the ends of the flap had been sutured into place. D, hand healed; swelling still present.

FIG. 4. Case 1. The scar which had contracted on the palm had been split and grafts taken from the thigh and sutured in. The margin of the flap had been adjusted to give more relaxation.

tated at the second joints. The skin from the outer surface of the hand behind these fingers with the underlying fat had been pinched off and was

hanging by a small pedicle near the wrist. The surgeon replaced the flap and started compressing. The flap began to slough after a few days and two weeks after the accident the patient was referred to us for treatment. (Fig.

FIG. 5. Case II. Degloved portion of the hand with the tendons exposed on the dorsal surface. The ends of the fingers had been amputated because they had been crushed. A double pedicle flap had been raised on the abdomen and sutured back with a sheet of rubber protective tissue beneath to prevent adherence of the flap to its base.

5.) The flap was removed and the area compressed for three days. The little finger was degloved as was the ring finger. The tendons of the outer half of the hand were exposed and were beginning to slough. A double pedicle flap was raised on the right abdomen and sutured back into place with a sheet of rubber protective tissue beneath. Ten days later the distal end of the flap was cut under local anesthesia and the following day attached to the denuded area on the hand. There was some infection but the flap held and

FIG. 6. Case II. Flap had been sutured over the exposed tendons. The stump of the little finger tended to flex. The scar was interfering with motion.

the tendons remained covered. Three weeks later the other end of the flap was cut and sutured into the hand covering the remaining raw area. The patient was discharged two weeks later. (Fig. 6.) Massage was started and function returned. However the little finger tended to stay flexed so the flap was shifted six months later with a satisfactory result. (Fig. 7.) The finger can now be used satisfactorily and he has resumed his occupation.

*Comment.* A pinched flap will very rarely survive and should not be sutured back if there is a question of exposed tendons. A double pedicle flap was delayed since a gauntlet flap could not be

FIG. 7. Case II. Six months later the flap was shifted to permit relaxation of the stump of the little finger. Note that the finger can now be laid straight. There is complete use of the stump.

used because of the position of the injury. The delay was necessary to insure the circulation from one end. Immediate action in covering the denuded area would have saved time and scar formation. The loss of the little finger would have made the hand useless in industry.

CASE III. A white male, age 28, and an electrician, was admitted to the hospital after falling against a high tension wire. His general condition was not very grave and he recovered quickly. There were several areas of burn on his arms and hands. The deepest and largest was on the inner aspect of the left wrist. There was a small area on the right wrist and one in the right

palm. The hands were greatly swollen for two weeks. The skin in the burned areas began to slough and the tendons of the left wrist became exposed. The area was two inches wide and three inches long. The patient was referred to

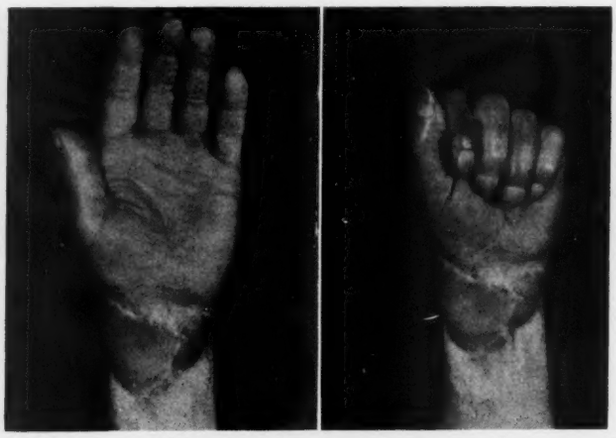

FIG. 8. Case III. A flap had been sutured over the exposed tendons on the inner side of the wrist. Note that the fingers can be flexed completely. There is complete use of the hand with normal function.

us concerning some procedure to save the tendons. A tubed flap was raised on the right abdomen. The tendons were dressed with iodiform gauze which kept them dry and delayed the slough. After two weeks the distal end of the flap was cut and the flap sutured over the denuded tendons. This flap

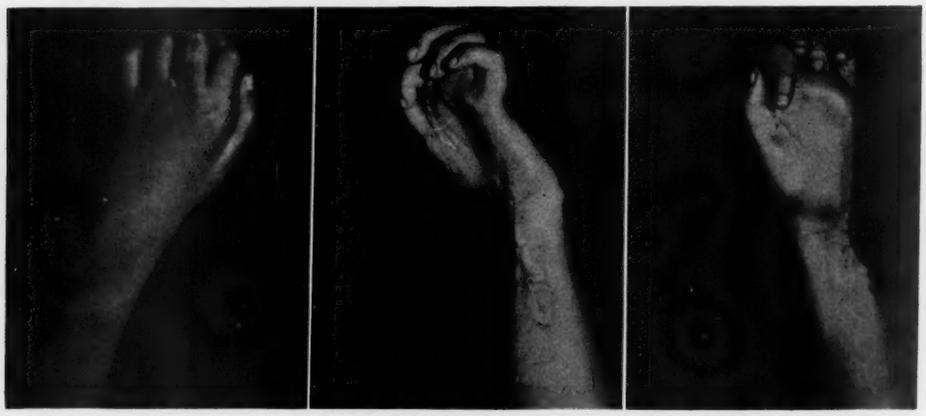

FIG. 9. Case IV. Claw deformity of the hand due to a loss of tendons in the wrist. The index finger is flexed by a scar band. There is no motion in the wrist. The fingers can be moved.

healed without infection and two weeks later the other end of the flap was sutured into place. The injury had caused the tendons to adhere and massage was started. After six months the tendons moved freely and perfect motion was secured. (Fig. 8.)

*Comment.* A tubed flap was used because it was most easily utilized. Tubing eliminated any raw areas to invite infection. Here one had to wait until the slough of the burned skin could be removed and there was no way to determine its extent sooner.

FIG. 10. Case IV. Tubed flap raised on the chest and abdominal wall; the tube is two weeks old. A rubber band was placed around the lower end and tied tightly constricting the circulation. The flap was cut on the following day. Note the bleeding from the stump. The rubber band was left on the stump on the abdomen to act as a hemostat.

CASE IV. A white male, age 10, received an electrical burn on the right wrist. He was treated for a long period of time until all of the tendons of the wrist had sloughed and the area had healed. This caused a marked flexion deformity of the hand with no function. (Fig. 9.) The index finger was flexed by a scar band. The scar on the wrist involved all of the tendons on the outer aspect of the palmar surface with a heavy scar attached to the bone. There was no motion at the wrist. He came for treatment eighteen months after the injury. A tubed flap was raised on the right side of the

FIG. 11. Case IV. The flap was sutured into the lower half of the scarred area. Two weeks later a rubber band was placed around the distal end of the flap and the flap cut off on the following day. Note the bleeding from the stump. The rubber band was left on the distal end to act as a hemostat.

chest and abdomen. (Fig. 10.) Two weeks after it was formed, a rubber band was tied at the lower end to cut off the circulation gradually. The next day the tube was cut just above the band. The following day the flap was opened along the scar of its formation one third its length and sutured into the wrist after the scar had been partly removed. The lower part of the scar was freed from the bone and cut in strips to simulate tendons. (Fig. 11.) Two weeks later the other end of the tube was severed and the flap opened and inserted into the defect made by removing the remainder of the scar.

The scar band on the index finger was released by a z plastic. (Fig. 12.) The flap healed and the wrist was straight with some function. In an extended position there was some power in the fingers but if the wrist was flexed the

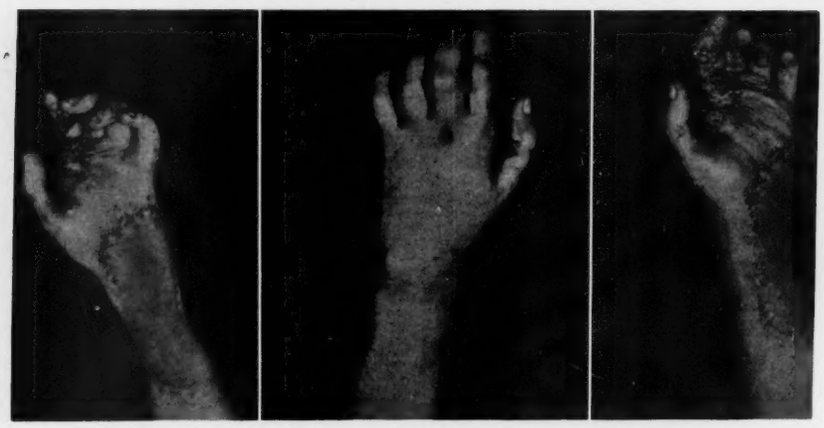

FIG. 12. Case IV. The distal end of the flap had been sutured into the wrist after the remainder of the scar had been removed. The wrist is now mobile. The scar was relaxed on the index finger permitting extension.

power was lost. The scar, acting as a tendon, was not short enough. One year later (Fig. 13) the patient returned. An incision was made near the margin of the flap on the forearm and the muscle bundle exposed. A second incision was made on the wrist where the tendon ends were massed in scar. Strips

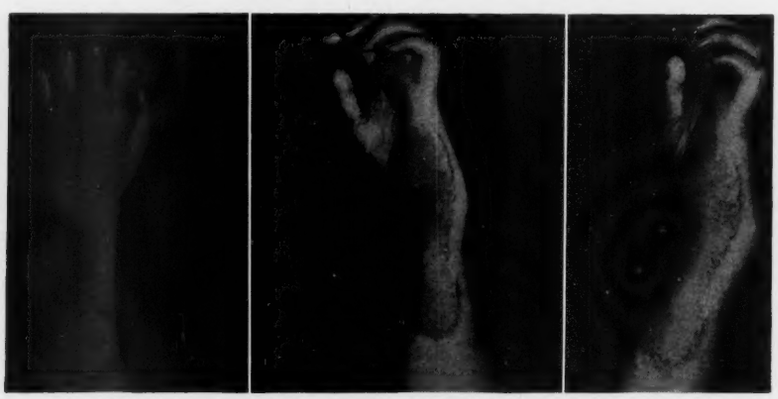

FIG. 13. Case IV. The hand one year later. There is flexion at the wrist but the fingers cannot act with the wrist extended. Strips of fascia were laced under the flap and attached to the end of the muscle bundle and the ends of the tendons in the wrist which were massed by scar. C, the wrist was flexed by the fascia to give more power to the fingers. There was an improvement in function.

of fascia lata were taken from the right thigh and the mass of muscle and the tendon ends laced with the wrist in a flexed position. Passive motion was started on the second day after operation and active motion was begun

one week later. The power of the fingers was greatly increased. Function was partly restored.

*Comment.* The tendons could probably have been saved by a flap before they had sloughed. The replacement of the scar with a bed of fat made it possible to attempt the use of fascia for tendons. The individual finger action could not be attained but a more useful hand was secured. Case 3 would probably have terminated in this fashion.

## SUMMARY

It is evident that tendons can be saved by the use of flaps even after they have begun to slough. Skin grafts will not take over exposed tendons and should not be attempted.

In cases where the skin has been injured by pressure, the chances of survival are so remote that valuable time will be saved if no attempt is made to preserve it.

The surgeon must select the type of flap which can be easily used in a given case. In Case I an immediate transfer was possible because a gauntlet flap could be used. In Case II, the flap was delayed because a single pedicle flap was desirable and this type could not be used immediately under the given conditions. In Cases III and IV, a tubed flap was used to avoid exposed granulations and because it insured the best take in the most comfortable position. Flaps from the back are not desirable because of the thickness of the skin and the uncomfortable position into which a patient with a hand injury would have to be placed.

Three cases are presented in which the function of the hands was saved to a degree sufficient to justify the time and trouble required.

In an industrial age in which competition is so great, these patients were re-established sufficiently to permit them to return to employment of some form and to keep them off of the long list of unemployed.

# AVULSION OF THE LOWER BICEPS BRACHII TENDON

## ANALYSIS OF FIFTY-ONE PREVIOUSLY UNREPORTED CASES

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AVULSION of the tendon of the biceps brachii at its radial insertion is a lesion rarely encountered. Because it occurs more frequently than one is led to believe from the few cases recorded in the surgical literature, and because of the perplexing problem it presents when one is for the first time suddenly and unexpectedly confronted with its repair, it is the purpose of this paper to report in detail two typical cases and add to the literature some fifty-one cases previously unreported, with a brief analysis and discussion pertaining to the diagnosis, operative repair and end results in this interesting condition.

Injuries to the biceps brachii muscle and tendons have up to the present time received scant and casual mention in most of the surgical textbooks. A great deal has been written referring to affections of the tendons of origin, however; and rupture, dislocation and elongation of the long head of this muscle have been frequently reported and discussed.

Gilcreest,[1] in an elaborate and comprehensive review of biceps tendon injury presented before the American College of Surgeons in 1933, analyzed one hundred cases and quoted Bianchieri[2] as reporting that of the three parts constituting the biceps, the long head is most frequently affected (96 per cent), next the lower tendon (3 per cent), and least of all the short head (1 per cent). At that time Gilcreest was able to find in the available literature only nineteen reported cases of rupture of the lower tendon and added three more from his series. He states that in the lower tendon, rupture usually occurs at or near its insertion into the radius and it would seem from his classified list that the three cases he was adding to the literature were avulsion cases.

In the 1939 *Year Book of General Surgery*, Graham[3] states that unlike rupture of the long head of the biceps, avulsion of the distal

[1] GILCREEST. *Surg., Gynec. & Obst.*, 58: 322–337, Feb. 1934.
[2] BIANCHIERI. *Chir. d. organi di movimento*, 9: 580–588, Bologna, 1925.
[3] The Year Book of General Surgery. P. 639. Chicago, 1939.

tendon from the radial tubercle is rare, only a dozen or so cases being on record. In my search of the literature, I was able to find only twenty-four cases in which the lower tendon had been completely avulsed from the tuberosity of the radius as demonstrated at operation. They are listed in Table 1 with the name of the surgeon, the method of repair, and the year reported.

The author's attention was called to this interesting lesion when, for the first time and within a period of nine months in 1937 to 1938, two cases were encountered at the Buffalo General Hospital. In each instance a diagnosis of rupture of the distal biceps tendon was made

TABLE 1

CASES OF LOWER BICEPS TENDON AVULSION PREVIOUSLY REPORTED

| Surgeon | Method of Dealing with Avulsed Tendon | Reported |
|---|---|---|
| 1. Acquaviva | Direct suture to bicipital tuberosity. | 1898 |
| 2. Bauman | Catgut woven into tendon end. Approximated tendon to radial tubercle. Brought suture ends through counter incision, dorsum forearm and tied them over gauze. | 1934 |
| 3. Benoiste-Pilloire | Calf tendon graft to bicipital tuberosity. | 1933 |
| 4. Bruning | Direct suture to bicipital tuberosity. | 1928 |
| 5. Ceconi | Direct suture to tuberosity and bicipital fascia. | 1930 |
| 6. Donhauser and Kenny | Sutured into antibrachial fascia. | 1939 |
| 7. Guibal and Ortscheit | Direct suture to bicipital tuberosity. | 1930 |
| 8. Guibal and Ortscheit | Sutured to tendon brachialis anticus. | 1933 |
| 9. Hahn | Direct suture to bicipital tuberosity. | 1909 |
| 10. Jeanneney | Direct suture tuberosity and bicipital fascia. | 1929 |
| 11. Kerschner | Nailed tendon to tuberosity. | 1928 |
| 12. Leavitt and Clements | Silk and chromic sutures woven into tendon and passed through drill holes in tuberosity and tied. | 1935 |
| 13. Lyle | Braided silk sutures woven into tendon and tied around shaft of radius. | 1932 |
| 14. Platt | Looped through hole drilled in radius. | 1931 |
| 15. Poli | Fastened to radius with loops of silk and kangaroo tendon. | 1938 |
| 16. Rocher | Direct suture to bicipital tuberosity. | 1913 |
| 17. Röfer | Sutured? | 1909 |
| 18. Rogers | By silk sutures through drill holes in tuberosity. | 1939 |
| 19. Schmieden | Sutured to bicipital fascia. | 1928 |
| 20. Seneque and Berthe | Sutured to periosteum of bicipital tuberosity. | 1935 |
| 21. Sonnenschein | Attached by means of drill hole and trap door in radius. | 1932 |
| 22. Stolze | Direct suture tuberosity and bicipital fascia. | 1928 |
| 23. Thomsen | Loops of strong silk threaded through tendon and passed through drill holes in tuberosity. | 1938 |
| 24. Wiesman | Direct suture to supinator longus and pronator radii. | 1906 |

preoperatively and avulsion from the radial tubercle was not suspected until demonstrated at operation. (Table 1.)

### AUTHOR'S CASE

*History of Injury.* D. C., male, age 43, was injured February 14, 1938. While moving oxygen tanks, one of them tipped and started to fall. In an attempt to prevent same, he quickly extended his right arm and caught the falling tank on the palm of his right hand. He, at the moment of forceful impact, felt a sudden "electric-like shock shoot up his entire right arm." He continued working though he observed considerable weakness and loss of power in the arm. Pain was not marked.

*Examination.* An examination was made twenty-four hours later. He complained of weakness, soreness and tenderness throughout the right forearm and arm. There was extensive ecchymosis on the anterior surface of the lower arm, throughout the anticubital fossa and extending down the ulnar half of the forearm. The anticubital fossa was moderately swollen and tender. Though one could not see the biceps tendon because of the swelling, it could be felt. It could not be made taut by active contraction of the biceps muscles, however. On comparing the two arms there was an obvious defect in the right, in that the belly of the biceps on contraction was located at a higher level. Flexion of the forearm, though comparatively weakened, caused little discomfort. It was thought that the power of supination was probably diminished. Diagnosis of rupture of the lower tendon of the biceps was made.

*Operation.* Operation was performed on February 21, 1938, the seventh day post-trauma, by the author. The incision extended obliquely across the right anticubital fossa. The median basilic vein was divided between ligatures. Fascia which was hemorrhagic was incised. The bicipital fascia which was hemorrhagic and edematous appeared to be intact. The biceps tendon, which had been avulsed from the radial tubercle, was lying quite free and loose between the brachioradialis muscle laterally and the pronator radii teres muscle medially. Its bulbous end appeared frayed and edematous. There was a small blood clot immediately beneath it. Considerable time was spent in trying to expose the tuberosity of the radius, which was unsuccessful and finally abandoned. The operator was impressed with the numerous important structures identified and confined in this anatomical region and was thoroughly convinced that exposure of the tubercle by this approach was both impractical and unwise. It seemed important that the power of supination be preserved even though it were only an accessory function of the biceps. This seemed to demand reattachment to the radius. On the other hand, it was recalled how difficult it was to determine definitely any loss of supinative power in the patient preoperatively and because of the apparent inaccessibility of the radial tubercle, it was decided to splice the biceps tendon into the well defined tendon of the

brachialis anticus muscle at its insertion into the base of the coronoid process of the ulna.

Repair was finally accomplished by splitting the tendon of the biceps in

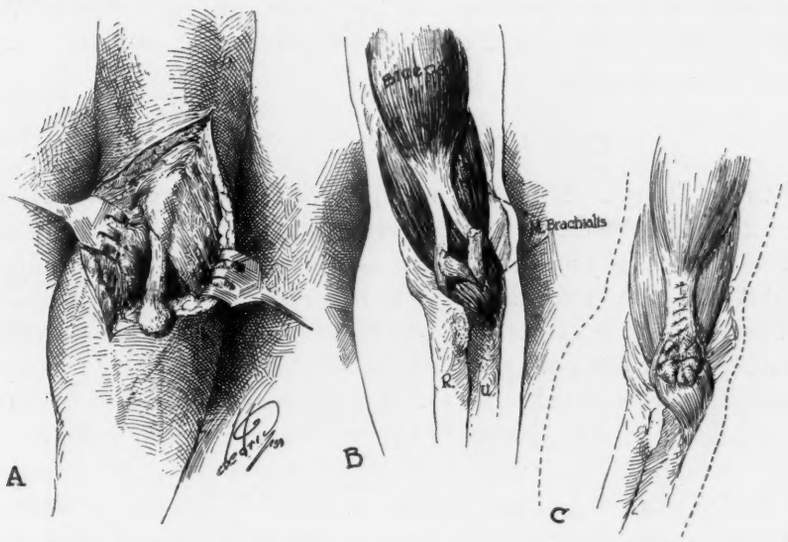


FIG. 1. Author's case. Method of repair. A, avulsed tendon end lying in operative field; B, tendon split and carried around and up through the tendon of the brachialis muscle at its insertion; C, splicing completed as shown with interrupted silk and chromic gut sutures.

a vertical plane and inserting these two halves of the tendon around and up through the tendon of the brachialis anticus muscle, immediately proximal to its insertion into the base of the coronoid process of the ulna. These two loops of the split biceps tendon were completed, fastened together and to the branchialis tendon as well, with interrupted chromic and silk sutures. The wound was then closed and a molded posterior plaster splint was applied with elbow fixed in right angle flexion. (Fig. 1.)

*Postoperative Care.* The splint was removed on the eleventh postoperative day at which time a sling was furnished and the patient was discharged from the hospital. There was at this time a noticeable small localized area of tender induration at the site of the tendon splicing.

He returned to light work March 23, 1938, the thirtieth postoperative day, and returned to his usual work April 25, 1938, two months postoperatively.

A note two months after operation stated that he was working steadily without complaint. His arm looked good. There was practically full range of motion. Power of flexion was good. Extension was still limited by 10 degrees. It was believed that power of supination was diminished but the extent of loss could not be estimated.

One year after injury function was completely restored as far as could be determined. Flexion power was normal as compared to the uninjured arm.

There was no objective dislocation of the contracted biceps belly and supinative power, though difficult to estimate, also appeared to be equal to that of the uninjured extremity. With the forearm flexed or extended, the patient could turn in supination and pronation, an eight pound Stillson wrench requiring torsion power of thirty-six pounds. He could do no better with the uninjured arm.

### CASE OF DR. W. W. PLUMMER

*History of Injury.* Dr. E. K., male, age 62, was injured June 21, 1937. While attempting to disengage his automobile bumper, which was interlocked with that of another car, he lifted suddenly and forcefully. He suffered severe pain in the lower right arm and forearm which was accompanied by a sensation of bursting which "seemed as though a tendon had ruptured." The severe pain was only momentary, he was able to move his arm and forearm, and other than noticeable weakness and tenderness to touch about the anterior surface of the elbow there was little discomfort.

*Examination.* The patient was examined on June 22, 1937, twenty-four hours later. The right forearm could be actively flexed almost completely but only with considerable pain. Power of flexion was noted to be greatly diminished. There was no marked swelling and no discoloration. There was an abnormal fullness on the medial aspect of the anticubital fossa. The outstanding objective sign was the position assumed by the actively contracted belly of the biceps muscle which was at a considerably higher level as compared to the left or uninjured arm. The lower tendon could not be identified. Diagnosis of ruptured distal tendon of the biceps was made.

*Operation.* Operation was performed on June 23, 1937, forty-eight hours post-trauma, by Dr. W. W. Plummer. A midline vertical incision was made across the anticubital fossa, and the fascia was incised. There was no subcutaneous hemorrhage. The bicipital fascia was intact. The biceps tendon appeared normal in all respects except that it seemed to be slack. Exposure and inspection of the tendon distal to its muscle expansion revealed nothing abnormal. However, when during inspection the tendon was lifted, the entire distal end suddenly and unexpectedly slipped out of its canal into the wound. It was observed that attached to the bulbous end there was a thin osseous flake which was presumed to come from the bicipital tuberosity. The operator was astonished. It seemed impractical to attempt exposure of the radial tubercle with its hazardous dissection. It was therefore planned to pull the tendon back through the canal and attempt to oppose it in its normal relation to the radius. This was accomplished by inserting a blunt instrument into the canal from which the tendon had been withdrawn. An incision was then made immediately over the point of the instrument on the dorsal surface of the forearm. This smaller incision was then enlarged to permit protrusion of the instrument and exposure of the adjacent ulnar shaft. Two small holes were drilled in the ulnar shaft and a

mattress suture of ox fascia, which had been previously attached to the tendon end, was guided through the canal and out through this dorsal incision. The loose ends of the ox fascia were then passed through the two

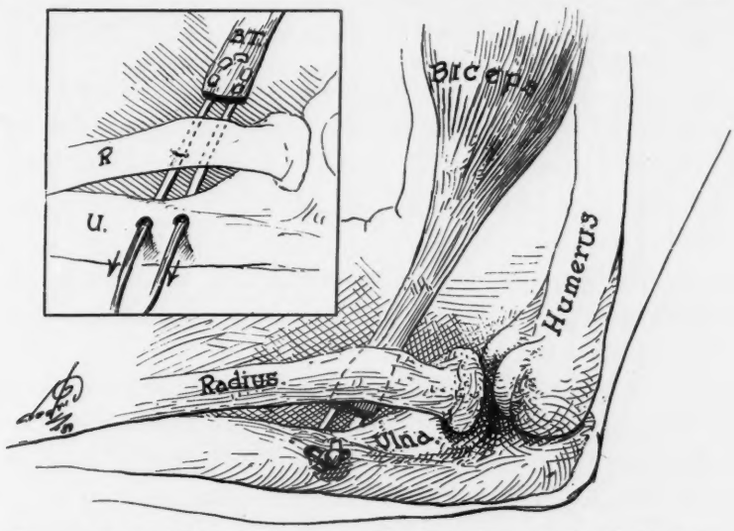


FIG. 2. Case of W. W. Plummer. Method of repair. Ox fascia woven into end of biceps tendon as shown in insert. Tendon approximated to ulna shaft adjacent to bicipital tuberosity by means of drill holes. (Counter incision over ulna required.)

holes in the ulna and the attached distal tendon of the biceps drawn back into its canal in such fashion as to oppose probably its avulsed surface to the site of the radial tubercle. The two ends of the ox fascia were then tied together over the ulna and the wounds were closed. The arm was then placed in a lateral moulded plaster splint with elbow in 90 degrees flexion. (Fig. 2.)

*Postoperative Care.* The patient was discharged from the hospital on the third day. Fixation dressing was removed at the end of one month after which function was resumed. Restoration of function was progressive and satisfactory and eventually complete.

These two cases were informally presented, shown and discussed at the meeting of the American Orthopedic Association held in Buffalo, New York, June, 1939. Following the presentation, several members mentioned cases they had treated and how repair was accomplished. From this experience and in spite of the fact that so few cases had been reported in the literature, it seemed that this lesion probably occurred more frequently than the reports would indicate or suggest.

When for the first time, one unexpectedly encounters this unusual condition in the operating room; he is obliged to resort to his own

ingenuity and it is, therefore, not surprising that the previously described methods of repair differ greatly. It is surprising and noteworthy, however, that the end results as reported were equally satisfactory and for the most part excellent in all cases, regardless of the method of repair.

This fact was so impressing that it occurred to the author that it would be desirable and worthwhile if a considerable number of cases could be collected and analyzed with the hope of establishing some precedent which might be used for the guidance of others called upon to care for this lesion.

It was believed that it might be possible to uncover unreported cases through correspondence with a group of qualified men distributed throughout the country.

In July, 1939, letters of inquiry were sent to the members of the American Surgical Association, The American Orthopedic Association and the American Association for the Surgery of Trauma. The response was most gratifying as shown in Table II.

TABLE II

| | Inquiries | Replies | Per Cent | Cases |
|---|---|---|---|---|
| American Surgical Association | 146 | 108 | 73.9 | 2 |
| American Orthopedic Association | 130 | 86 | 66.1 | 11 |
| American Association for the Surgery of Trauma | 191 | 141 | 73.8 | 23 |
| Special references | 23 | 20 | 87.0 | 15 |
| Total | 490 | 355 | 72.6 | 51 |

The correspondents were, almost without exception, most gracious and generous in furnishing me with data pertaining to their own cases, and many referred me to colleagues or associates who had encountered and operated upon this lesion.

As the result of their great kindness, it is possible to record and briefly analyze fifty-one cases of lower biceps tendon avulsion from the bicipital tuberosity of the radius.

Only those cases which presented unquestionable evidence of complete tendon avulsion as demonstrated at operation are included. In these cases the operator specifically described avulsion and in many instances commented upon the "frayed bulbous tendon end," "periosteal flecks or plaques in the tendon end," or mentioned avulsion with the "bicipital tuberosity remaining clean except for a fringe of tendon remnant along the posterior edge of the tuberosity."

TABLE III

FIFTY-ONE CASES OF LOWER BICEPS TENDON AVULSION PREVIOUSLY UNREPORTED

| No. Case of Dr. | Year | Sex | Age | Technic of Operative Repair | Result |
|---|---|---|---|---|---|
| 1. Aitken, A. P..... | | M | 60 | Suturing biceps tendon to tendon of brachialis anticus muscle. | Excellent |
| 2. Andrews, B..... | 34 | M | 45 | Biceps tendon looped through brachioradialis muscle. | Excellent |
| 3. Badgley, C. and Mitchell, C. L..... | 30 | M | 45 | Biceps tendon sutured to tendon of brachialis anticus muscle. | Excellent |
| 4. Bates, W..... | 21 | M | 38 | Biceps tendon sutured to frayed tendon remnants on bicipital tuberosity. (Chromic gut.) | Good |
| 5. Bates, W..... | 34 | M | 45 | Biceps tendon sutured to frayed tendon remnants on bicipital tuberosity. (Chromic gut.) | |
| 6. Bates, W..... | 39 | M | 45 | Biceps tendon sutured to frayed tendon remnants on bicipital tuberosity. | Good |
| 7. Buckner, H..... | | | | Fascial graft looped around neck of radius and sutured to biceps muscle. | Good |
| 8. Bunnell, S..... | 28 | M | 59 | Fascial graft through drill hole in bicipital tuberosity. | Good |
| 9. Bunnell, S..... | 30 | M | 35 | Drill holes bicipital tuberosity. (Silk.) | Excellent |
| 10. Bunnell, S..... | 32 | M | 52 | Drill holes bicipital tuberosity. (Silk.) | Excellent |
| 11. Coley, B..... | | | | Drill holes bicipital tuberosity. (Silk.) | Excellent |
| 12. Coley, B..... | | | | Biceps sutured to tendon fringe on bicipital tuberosity. | Excellent |
| 13. Dobbie, R. P.*... | 38 | M | 43 | Tendon split and spliced into tendon of brachialis anticus muscle. (Chromic gut and silk.) | Excellent |
| 14. Dudley, H..... | | | | Tendon biceps split, part sutured to subperiosteal bed in bicipital tuberosity, other part looped around radius and sutured to self. | Good |
| 15. Gallie, W. E..... | 34 | M | | Fascial graft looped around shaft radius. | Excellent |
| 16. Gallie, W. E..... | 36 | M | | Fascial graft through drill hole bicipital tuberosity. | Excellent |
| 17. Gallie, W. E..... | 38 | M | | Semitenonosus graft through drill hole bicipital tuberosity. | Excellent |

TABLE III. (*Continued*)

| No. Case of Dr. | Year | Sex | Age | Technic of Operative Repair | Result |
|---|---|---|---|---|---|
| 18. Ghormley, R..... | 38 | M | 49 | Drill holes bicipital tuberosity. (Fishline.) | Excellent |
| 19. Grace, R. V..... | 37 | M | 50 | Biceps tendon sutured to frayed tendon remnants on bicipital tuberosity. (Silk.) | Excellent |
| 20. Hammond, R..... | 35 | M | 46 | Mattress chromic suture, connecting tendon to frayed tendon remnant attached to bicipital tuberosity. | Good |
| 21. Hawkins, T..... | | M | | Drill holes bicipital tuberosity. (Silk.) | Good |
| 22. Hedrick, D. and Mitchell, C. L..... | 37 | M | 48 | Biceps tendon sutured to fascia of brachialis anticus. (Silk.) | Good |
| 23. Henry, M. O..... | | | | Drill holes bicipital tuberosity. (Chromic cat gut.) | |
| 24. Howard, N..... | 35 | M | 35 | Biceps tendon sutured to frayed tendon remnants on bicipital tuberosity. (Silk and periosteum.) | Excellent |
| 25. Landenberger, J... | | | | Drill holes bicipital tuberosity. (Chromic gut.) | Excellent |
| 26. Landenberger, J... | | | | Drill holes bicipital tuberosity. (Chromic gut.) | Excellent |
| 27. Leavitt and King. | 36 | M | 60 | Drill holes bicipital tuberosity. (Chromic gut.) | Excellent |
| 28. Marble, H. C..... | | M | 70 | Biceps tendon sutured to frayed tendon remnants on bicipital tuberosity. (Silk.) | |
| 29. Marble, H. D..... | | M | | Fascial graft looped around neck radius. | |
| 30. McGaw, W. H.... | 37 | M | 44 | Fascial graft, drill holes bicipital tuberosity (Silk.) | Good |
| 31. Moore, J. R..... | 39 | M | 52 | Biceps tendon sutured to lacertus fibrosus and brachialis anticus muscle. | Too early to state |
| 32. Morrison, G..... | | M | 62 | Biceps tendon passed through lacertus fibrosus and sutured to self. | Excellent |
| 33. Nachlas, I. W..... | | M | | Biceps tendon sutured to adjacent fascia. | Excellent |
| 34. Olson, F. A..... | 37 | M | 39 | Drill holes, bicipital tuberosity silver wire loop. | Good |
| 35. Patton, C. L..... | 31 | M | 61 | Drill holes bicipital tuberosity. (Chromic gut.) | Excellent |
| 36. Perkins, R. S..... | 38 | M | 45 | Drill hole bicipital tuberosity. (Silk.) | Fair |

TABLE III. (*Continued*)

| No. Case of Dr. | Year | Sex | Age | Technic of Operative Repair | Result |
|---|---|---|---|---|---|
| 37. Perkins, R. S..... | 39 | M | 41 | Drill hole bicipital tuberosity. (Silk.) | Excellent |
| 38. Plummer, W. W.*. | 37 | M | 62 | Biceps tendon attached to ulna opposite bicipital tuberosity by means of drill holes and ox fascia. | Excellent |
| 39. Porter, E. M..... | | | | Sufficient fringe on tubercle, reattachment tendon by heavy silk sutures. | Excellent |
| 40. Rogers, W. A..... | | M | | Fascia graft through drill hole bicipital tuberosity. | Excellent |
| 41. Sherrill, J. and Conwell, H. E.... | 39 | M | 60 | Drill holes bicipital tuberosity. (Silk.) | Good |
| 42. Smith, M..... | 32 | M | 45 | Drill holes bicipital tuberosity. (Silk.) | Excellent |
| 43. Sonnenschein, H.. | 33 | M | 50 | Tendon looped through slot in bicipital tuberosity. | Excellent |
| 44. Sonnenschein, H.. | 34 | M | 56 | Tendon looped through slot in bicipital tuberosity. | Excellent |
| 45. Strickler, F..... | 33 | M | 50 | Fascial graft, drill holes bicipital tuberosity. (Chromic gut.) | Excellent |
| 46. Sweaney, H..... | 36 | M | 57 | Biceps tendon sutured to frayed tendon remnants on tubercle and lacertus fibrosus. | Good |
| 47. Venable, C..... | | | | Drill hole in radius and suture. | Excellent |
| 48. Wiley, E. H..... | 16 | | | Reattachment bicipital tuberosity. (Chromic gut.) | Excellent |
| 49. Williamson, E..... | 38 | M | 67 | Biceps tendon sutured to adjacent muscle and lacertus fibrosus. | Too early to state |
| 50. Wilson, P. D..... | | M | | Fascial graft, drill holes bicipital tuberosity. | Excellent |
| 51. Wyckoff, H. and Maxson, F..... | 38 | M | | Fascial graft, tunnel in bicipital tuberosity. | Excellent |

* Case report in detail in this paper.

Cases reported as being ruptured close to or proximal to the bicipital tuberosity were excluded, as were several cases associated with or complicated by fractures. Several cases reported, presented typical history, signs and symptoms but were excluded because they were not operated.

The cases reported in Table III have never been previously recorded in the literature. Operator, method of repair, year, sex, age

and end results are the essential data which space will permit recording.

Considerable more data are available than was displayed in the preceding tabular outline of cases and follow:

*Sex Incidence.* In all cases where sex was mentioned (forty-one) the injured was a male. This is also true in all cases previously reported in the literature.

*Age Incidence.* There were thirty two cases in which the age was stated. The oldest, seventy, the youngest, thirty-five, the average age was fifty-one.

*Arm Affected.* The arm (right or left) was stated in only twenty-six of the fifty-one cases. Of these, the lesion was seen in the right arm twenty-one times, in the left arm five times. It seemed for the most part to depend on whether the individual was right or left handed.

*Indirect Violence.* In all cases in which the nature or mechanism of the trauma was furnished, violence was indirect in type. Considerable extension force suddenly applied to a resisting, actively flexed forearm was almost invariably described. The mechanisms more frequently mentioned included lifting, pulling and straining at heavy objects, cranking automobiles, catching another falling person or object of considerable weight, attempting to break fall by grasping at passing objects, lifting ends of automobiles in an effort to disengage entangled bumpers, etc.

In discussing the exciting cause of this uncommon lesion, it should be stated that of the cases here reported five patients were physicians. The violence described in these physicians is typical as well as interesting and follows:

Case 18 was lifting the front end of an automobile.

Case 38 was lifting on front bumper of automobile.

Case 41 made a playful pass at daughter's "rear end," and was said to have missed.

Case 46 was cranking automobile.

Case 50 was delivering obstetrical case with forceps.

## DIAGNOSTIC FEATURES

Though it is not possible to differentiate preoperatively between avulsion of the tendon from the bicipital tuberosity of the radius, and rupture of the tendon proximal to its radial insertion, it should be recognized that either may occur and both require surgical repair.

Loss in continuity of the tendon is all that one can be expected to appreciate and this is not difficult.

Not a few of the patients reported to the surgeon that they thought they had "torn or ripped a tendon or muscle." As one might expect, the subjective complaints varied considerably with the individual and the time elapsed since injury, but several were conspicuously constant.

### SUBJECTIVE COMPLAINTS

1. Tearing sensation in the lower arm or upper forearm (region anterior elbow) at the time of violence.
2. At time of violence, sudden pain of short duration (usually not marked).
3. Varying degrees of disability (usually considerable) as manifested chiefly in complaint of diminished power of forearm flexion, and also to a lesser degree, diminished power of supination.
4. Soreness in lower arm and upper forearm (anticubital fossa) during the first few days immediately following injury.

### OBJECTIVE SIGNS

The objective signs are unmistakable and diagnostic. It must be remembered that variations are to be expected, dependent upon the type of individual, muscular development, and length of time between trauma and examination. In general, and as a rule, the following signs are to be expected and were observed:

1. Swelling, tenderness and ecchymosis in the anticubital region (early).
2. Gross, definite weakness in power of flexion, and to a lesser degree supination. It is to be remembered that flexion is possible and often complete, and though often painful, is not necessarily so; also that it may be difficult or impossible to demonstrate any loss in supinative power.
3. The belly of the contracted biceps muscle is more prominent and retracts to a higher level in the affected arm. This is usually quite striking.
4. The biceps tendon and the lacertus fibrosus, which when the forearm is flexed, are normally palpable and tense, are, in the injured arm, slack and difficult or impossible to identify definitely.
5. There is a visable and palpable depression or defect in the anticubital fossa where the normal tense tendon and fascia should be.

### OPERATIVE FINDINGS

In almost all instances the preoperative diagnosis was rupture of the distal biceps tendon. As previously mentioned, one readily recognizes a disruption in the continuity of the tendon, but unless avulsion has been previously encountered, it is not anticipated. These fifty-one cases were operated upon by forty surgeons and only eight of these surgeons have encountered the condition more than once. Bates, Bunnell, Gallie and Sonnenschein have each operated this lesion three times; Coley, Landenberger, Marble and Perkins, two times.

The cases previously reported in the literature are few and for the most part foreign, so it is not surprising that most of the operators were astonished to find an avulsed tendon and a clean bicipital tuberosity rather than a tendon lacerated or ruptured proximal to its insertion.

A quite different and more difficult problem presents itself when, instead of being able to suture the adjacent lacerated ends of a good-sized superficial tendon, it becomes necessary or seems desirable to secure reattachment of the tendon to the radius, the adequate exposure of which is difficult and not without danger.

In about 25 per cent of these cases, considerable time elapsed before operation (several weeks to several months). The description as to the appearance and state of the tissues and structures naturally varied accordingly.

*Hemorrhage* was as a rule not extensive or marked. In most cases it was described as slight, in a few, marked or entirely absent.

*Bicipital Fascia (lacertus fibrosus).* In most cases it appeared to be intact, in many others it was lacerated in varying degrees.

*Biceps Tendon.* The description of its appearance and position varied considerably. In all cases it was described as having been completely avulsed from the bicipital tuberosity of the radius. A bulbous, expanded, distal end, showing interlacing tendinous fibers and occasional flecks or plaques of bone and periosteum was frequently mentioned.

In many instances the position of the tendon appeared to be normal except that it was observed to be slack.* Dr. Plummer's description is more or less typical and was repeated many times as the finding in these cases. Where little or no displacement of the tendon was observed the bicipital fascia was noted to be intact. On

* See detail case report.

the other hand, marked retraction of the tendon upward into the lower arm was also frequently observed and the tendon was described as being coiled upon itself at various levels in the arm. This almost invariably occurred in those cases in which the lacertus fibrosus had been lacerated and considerable time had elapsed before operation. It was in these cases, in which upward retraction of the tendon was marked and considerable time had elapsed, that fascial and tendinous grafts were utilized in securing reattachment to the radius.

*Bicipital Tuberosity of the Radius.* The distal tendon of the biceps is normally inserted into the posterior border of the bicipital tuberosity. Most of the operators commented upon the completeness of the avulsion and the clean appearance of the remaining tuberosity. Others described frayed tendon fringe or remnants remaining along the posterior margin or ridge of the tubercle. In some instances this apparently permitted or aided direct suture, e.g., Cases 4, 5, 6, 12, 18, 19, 23, 27, 38, 45, 47. Still others, because of the appearance of the distal end of the tendon, assumed the tubercle to be clean and in view of the method of repair, did not expose or inspect the tubercle, e.g., Cases 1, 2, 3, 13, 22, 31, 32, 33, 38, 49.

## OPERATIVE REPAIR

Incision was invariably in the anticubital region, vertically or obliquely placed and extending for varying distances upward on the arm and downward to the forearm. In only three instances, an additional smaller incision was made over the lateral or dorsal surface of the upper forearm to facilitate exposure of, and work on the bicipital tuberosity, e.g., Cases 16, 38, 48.

When one identifies in the field of operation the avulsed tendon end, it immediately occurs to him that it is most desirable to reattach the tendon to its original point of insertion, the bicipital tuberosity of the radius. He recalls that the biceps is the most efficient flexor of the forearm and that it is also a powerful supinator. To re-establish these functions seems imperative, and an effort is made to expose the tubercle. This is not easy. One only has to review the anatomy of this region to appreciate its depth, and the many important structures it is necessary to expose and identify and, at the same time, protect from injury. It is surprising and impressive to see in such a small field, so many structures, the injury of any one of which might cause serious complications and permanent disability greater than that which is being relieved.

In the series of twenty-four previously reported cases (Table I) as well as the series of fifty-one previously unreported cases (Table III), many different methods of accomplishing repair are described. They all fall into one of two major groups, however, depending on whether the tendon was attached to the radius or to other structures in the upper forearm.

Of the twenty-four previously reported cases, in twenty or 83 per cent, the tendon was reattached to the radius, which required exposure of the bicipital tuberosity. In four cases or 17 per cent, the bicipital tuberosity was not exposed but instead the tendon was attached to structures in the forearm other than the radius.

### METHOD OF REPAIR TWENTY-FOUR CASES PREVIOUSLY REPORTED (TABLE I)

Direct attachment to the radius: twenty cases or 83 per cent.

1. 8 cases—Tendon attached directly to the bicipital tuberosity by suturing to periosteum and frayed tendon fringe remaining on the tubercle. Cases: 1, 3, 4, 7, 9, 16, 17, 20.
2. 3 cases—Tendon attached directly to the bicipital tuberosity by suturing to periosteum and frayed tendon fringe remaining on the tubercle and additional suture to the bicipital fascia. Cases: 5, 10, 22.
3. 5 cases—Tendon attached to bicipital tuberosity by means of drill holes and suture material. Cases: 12, 14, 18, 21, 23.
4. 2 cases—Tendon tied around radius by means of attached sutures. Cases: 13, 15.
5. 1 case—Tendon nailed to radius. Case: 11.
6. 1 case—Tendon held opposed to bicipital tuberosity by means of suture transfixing forearm. Case: 2.

Attachment to structures in the forearm other than radius: four cases or 17 per cent.

7. 4 cases—Tendon sutured to bicipital fascia. Cases: 1, 6. Tendon sutured to brachialis anticus. Case: 8. Tendon sutured to brachioradialis and pronator radii teres. Case: 24.

The end result in all of these cases was invariably reported as good or excellent, and regardless of the operative procedure, it was stated or inferred that loss of function was nil or negligible. No complications were recorded.

Upon analysis of the fifty-one cases in the present series, similar end results were observed.

In forty-one cases or 80 per cent the tendon was reattached to the radius and in most instances to the bicipital tuberosity. Drill holes, slots, loops, grafts of fascia or tendon and various suture materials were described as being used.

In ten cases or 20 per cent the bicipital tuberosity was not exposed, and repair was accomplished by attachment of the tendon to structures other than the radius. Summary of methods of repair follows:

METHOD OF REPAIR IN FIFTY-ONE CASES PRESENT SERIES (TABLE III)

Direct attachment to radius: forty-one cases or 80 per cent.

1. 16 cases—Tendon attached to bicipital tuberosity by means of drill holes and suture material. Cases: 9, 10, 11, 18, 21, 23, 25, 26, 27, 34, 35, 36, 37, 41, 42, 47. Suture material: silk seven cases, chromic gut five cases, wire and fishline one case each, material not stated in two cases.
2. 11 cases—Fascial graft woven into or sutured to tendon which was then:
   (a) passed through hole or holes drilled in bicipital tuberosity. Cases: 8, 16, 30, 40, 45, 50, 51.
   (b) looped around upper third of radius. Cases: 7, 15, 29.
   (c) semitendonosus graft woven into biceps tendon, passed through drill hole in bicipital tuberosity and knotted. Case: 17.
3. 11 cases—Tendon attached to bicipital tuberosity by suturing to periosteum and frayed tendon fringe remaining on tubercle. Cases: 4, 5, 6, 12, 19, 20, 24, 28, 39, 46, 48. Suture material: silk seven cases, chromic gut four cases.
4. 2 cases—Tendon looped through slot in tuberosity. Cases: 43, 44.
5. 1 case—Tendon of biceps split. Part sutured to subperiosteal bed in bicipital tuberosity, other part of tendon looped around radius and fastened to self. Case: 14.

Attachment to structures in forearm other than radius: ten cases or 20 per cent.

6. 4 cases—Tendon sutured to or into tendon of brachialis anticus muscle. Cases: 1, 3, 13, 22.
7. 4 cases—Tendon sutured to or looped through lacertus fibrosus. Cases: 31, 32, 33, 49.

8. 1 case—Tendon looped through brachioradialis muscle. Case: 2.
9. 1 case—Tendon attached to ulna opposite bicipital tuberosity by means of drill holes and ox fascia. Case: 38.

In forty-one or 80 per cent of these cases the bicipital tuberosity was exposed.

In twenty-six or 50 per cent drill holes, slots or tunnels were said to have been inserted in the tuberosity to facilitate attachment of the tendon. As mentioned, to expose and drill the tuberosity requires a skillful bit of dissection and a fair knowledge of anatomy. It is surprising the number of times this method was chosen and performed and it is most creditable that complications were reported to follow this procedure on only three occasions. McGaw (30), reported postoperative radial nerve palsy in his case, but recovery of nerve function was said to be complete within six weeks and final end result was recorded as good. Sherrill and Conwell (41), reported radial nerve palsy subsequent to operation, which still existed after fifteen months in spite of recent unsuccessful surgical attempt at correction. As is so often the case, this single instance of serious disability would and did occur in a surgeon. Perkins (36), reported that his patient subsequently developed myositis ossificans with considerable disability about the elbow joint which accounts for the only "fair" end result reported in the entire group of cases.

With all due respect for the ability of this group of prominent and capable surgeons, it seems that for the most part they were endowed with considerable good fortune and it would perhaps not be amiss to venture the guess that in many instances relief was felt and expressed when, the day after operation, examination revealed normal sensory and motor innervation.

In the ten cases in which the bicipital tuberosity was not exposed, it was of course necessary to reattach the tendon of the biceps to structures other than the radius. In all but one instance (Case 38) this was accomplished by utilizing adjacent soft parts. In these few cases there were, as might be expected, no complications reported and the functional end result as reported was equally as good as in those cases in which the tendon was reattached to the radius.

### POSTOPERATIVE TREATMENT

The postoperative care was with slight variation quite similar in the great majority of cases. Immobilization was accomplished by

means of a molded plaster splint, arm and forearm included. Forearm was held in 90 degrees flexion and though it was not stated whether the forearm was in supinated, pronated or neutral position, it would seem as though the supinated or neutral positions were more desirable in order to lessen the tension and pull of the biceps tendon during the healing period.

The period of immobilization ranged from seven days to six weeks, after which active use and motion were permitted and encouraged. The patients as a rule recovered function progressively and rapidly and with few exceptions returned to work at a relatively early date. It was frequently reported that full or practically full function was restored within a period of three months. Complete extension seemed to be the last function obtained in most instances.

At the end of a year it was difficult to detect any residual disability and were it not for the scar of operation, this would often be impossible.

### END RESULTS IN FIFTY-ONE PATIENTS OPERATED UPON

In six of the fifty-one cases the end result was not stated, either because not sufficient time had elapsed for estimation or because the available notes did not record the end results. In only one instance was the result recorded as "fair" and in all others (forty-four cases) it was recorded as "excellent" or "good."

It is appreciated that these terms are not specific or particularly satisfactory when describing end results, but it is to be assumed from the comments furnished by the individual surgeons reporting their

TABLE IV
REPORTED END RESULTS (FORTY-FIVE CASES)

| Type of Repair | Total Cases | Excellent | | Good | | Fair | |
|---|---|---|---|---|---|---|---|
| | | Cases | Per Cent | Cases | Per Cent | Cases | Per Cent |
| Group 1. Cases in which repair required exposure of the bicipital tuberosity. (3 complications).... | 37 | 25 | 67.5 | 11 | 29.7 | 1 | 2.7 |
| Group 2. Cases repaired without the exposure of the bicipital tuberosity. (no complications)... | 8 | 7 | 87.5 | 1 | 12.5 | 0 | |
| Combined Groups 1 and 2. All cases regardless of the method of repair. | 45 | 32 | 71.1 | 12 | 26.6 | 1 | 2.2 |

44 cases or 97.7 per cent excellent or good restoration of function.

cases that the descriptive term "excellent" was used when function (power and range of motion) was fully restored. The term "good" was used when the patient was restored to a degree of economic usefulness equal to that enjoyed prior to injury, and where disability was recorded as being negligible or less than 10 per cent. (Table IV.)

### DISCUSSION AND COMPARISON OF END RESULTS ACCORDING TO METHOD OF REPAIR

It is obvious that the main function of the biceps is forearm flexion and this was completely restored in all but one case. *This single exception developed myositis ossificans subsequent to injury and operation. In two other cases complicated by postoperative nerve palsy, the restoration of function was specifically described as good in spite of nerve complication.* Loss of this main function, whether it be in power or range of motion, is easily demonstrated and estimated. In this group of cases, preoperative loss in flexion power was constant and outstanding. At the same time it was observed that loss in power of supination was in no way as constant or conspicuous and in the author's case, reported in detail, though biceps supinative power was known to be lost, it was impossible to demonstrate definitely its absence, either pre- or postoperatively. It seems that this can be logically accounted for in that the lesion occurs in middle aged and elderly, muscular males, and well developed forearm muscles readily compensate for any loss in biceps supinative power. These observations are significant as it becomes apparent that the supinative power of the biceps is of secondary importance and that the primary objective of repair should be the restoration of flexion power.

In reviewing the end results said to have been obtained in the twenty-four previously reported cases, and the fifty-one cases of this series, seventy-five in all, it appears to have been shown that equally effective and satisfactory functional recovery is obtained when the tendon is attached to either the radius or the adjacent upper forearm soft parts. It follows, therefore, that direct reattachment of the tendon to the radius is unnecessary. In the group of forty-one cases of this series, in which reattachment to the radius was accomplished, complications causing serious permanent disability occurred twice (4.8 per cent). This fact suggests that in addition to being unnecessary, it is perhaps impractical and unwise to select a procedure more difficult, dangerous and time consuming when the same result can be obtained with less effort and without the asso-

ciated risk of serious complication, which attends exposure of the bicipital tuberosity when approached through the anticubital fossa.

## CONCLUSION

1. Avulsion of the lower tendon of the biceps brachii from its insertion into the bicipital tuberosity of the radius, though uncommon, is not as rare as is suggested by the few recorded case reports.

2. The history of injury, subjective symptoms and objective signs are quite constant and diagnostic.

3. The lesion is disabling and requires operative repair. Many methods have been used and all seem to result in satisfactory restoration of function.

4. Repair of this condition, when unexpectedly encountered for the first time is a perplexing problem to the surgeon because of the desire to restore supinative as well as flexion power. Loss in power of forearm flexion is the outstanding complaint and disability and the chief objective of operative repair should be its restoration. The supinative power of the biceps is of secondary importance and can be ignored, for when it is lost, it is adequately compensated for by the muscles of the forearm.

5. Direct reattachment of the tendon to the upper radius is difficult to accomplish, time consuming and not without danger.

6. Other methods of repair less difficult and dangerous are equally effective and reported end results justify their use.

## SUMMARY

1. Twenty-four previously reported cases of lower biceps tendon avulsion are reviewed and fifty-one additional cases as reported by forty surgeons, are analyzed and added to the literature.

2. Two of these cases are reported in detail because they are typical and the methods of repair used are in addition to being unique, simple and satisfactory.

3. The mechanism of injury, diagnostic features, operative findings and methods of repair are described and discussed.

4. Attention is called to the dangers and complications associated with exposure of the bicipital tuberosity.

5. End results are evaluated and compared.

6. Simpler methods of reattaching the tendon to forearm soft part structures are recommended.

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# BILATERAL, INDEPENDENT RUPTURE OF THE LONG HEAD DIVISION OF THE BICEPS BRACHII

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THE purpose of this short communication is four-fold: (1) A *coup d'oeil* of the literature indicates that bilateral, independent rupture of the biceps is almost unknown. (2) Rupture of a muscle or tendon is a distinct entity produced by overwrought muscular contraction. Ruptures of muscles and tendons are not associated with blows, contusions, or open wounds. For example, Lecène and Moulonguet,[6] writing in *Précis de Pathologie Chirurgicale*, say that "one must reserve the name of muscular rupture to the solution of continuity of the muscle produced in the course and under the influence of contraction." They quote Lejars as supporting the same opinion. In a following statement they say, in effect, that one thus eliminates from the group of true muscular ruptures those that are associated with direct injury, like blows upon a contracted muscle, the latter placing the injury in the category of contusions, and being, at the same time, "veritable fractures of the muscle." (3) Advanced age, with sclerosis, and other senile changes may be regarded as predisposing causes, but not as active concomitant causes. (4) It is believed by the reporter that a substandard physique in the case of a young individual, essentially normal in every respect, may exert a tremendously important etiological influence. This is illustrated by the following report:

A young man, thirty-one years of age, consulted us on December 13, 1934. He complained of weakness, discomfort and awkwardness of both arms, with an enlargement in the front lower brachial region on each side.

According to the history, he was shoveling wheat into a truck one and one-half years before we saw him, and while engaged in that occupation there was sudden, mild, cramping pain in the lower part of the front of the left upper arm, and quickly after that the appearance of a mass about the size of an ordinary egg in the left lower brachial region. The arm was weak, and he was uncomfortable. There was no history of a "snap" at the time

* Dr. Long passed away on October 27, 1940.

of the injury. Regardless of his discomfort, he continued to work as a trucker, taking part in the loading and unloading of the truck.

The general health had always been good. Physically, he was a very small man. The height was 62½ inches, weight 137 pounds. In general, the muscular system appeared to be well developed for an individual of his size. Continuing to work as a trucker, he was greatly annoyed by the weakness of the left arm, and the enlargement which was always present.

About six or eight months after the difficulty in the left arm had developed, he was handling and hauling sand, and about that time an enlargement appeared on the front part of the lower right upper arm. He was under the impression that it had appeared rather slowly, but the enlargement was persistent, and there was weakness and general disability of the right arm.

Examination of the left arm showed a prominent, rather firm enlargement about 2½ inches in diameter on the front part of the lower left upper arm. When the arm was flexed against resistance, this mass became more tense and somewhat larger. It appeared to be distinctly circumscribed. Its contour was not entirely regular, there being a small depression between the outer side and the inner side of the mass. The mass on the outer side appeared to be a good deal smaller than that on the inner side. There was a slight depression in the front part of the left upper arm just above the mass. In examining the patient, it was believed that the tendon of the long head of the biceps could be palpated when the arm was flexed and extended.

In the front of the right lower upper arm there was a similar mass, but a good deal larger than that on the left. This mass in the right arm measured about 3½ by 3½ inches. It was rather soft when the arm was at rest, but became more firm when the arm was flexed against resistance. However, it did not become as firm as the mass on the front of the lower left upper arm. It was believed that the tendon of the long head of the biceps could be palpated when the arm was flexed and extended. The diagnosis was bilateral, independent, ancient ruptures of the biceps brachii, and it was believed that the pathology was in connection with the long head side of the muscle, with a probability that there had been damage, and possibly dislocation of the long head tendon on the left side. (Figs. 1 and 2.)

Taking into consideration the length of time that had elapsed from the injury to the first examination of patient—about eighteen months in the case of the left side, and about ten or twelve months in the case of the right side—and taking into consideration, at the same time, the very irregular outline of the mass on the left side, we had some doubt as to the advisability of undertaking an operation. It was finally decided to do an operation on the left side only, leaving the right side alone, pending subsequent developments.

An incision was made through the skin and fascia over the front part of the left upper arm, extending from a point near the supraglenoid attach-

ment of the long head to the lower part of the left upper arm just above the elbow.

The sheath of the biceps was apparently present. It was divided in a

FIG. 1. Left arm, about eighteen months after sudden development of swelling.

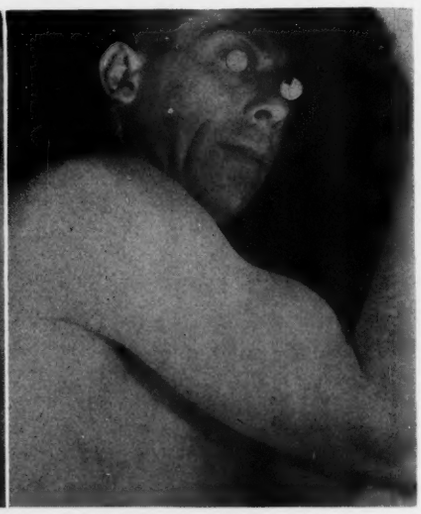

FIG. 2. Same patient, right arm, ten or twelve months after swelling was first noticed. Enlargement was gradual.

vertical direction, and the structures explored. There did not appear to be a detachment of the long head of the biceps, but the muscular fibers had been stripped from the tendon and rolled up into an irregular mass in the front part of the lower left upper arm. The mass was fixed by the development of new tissue, like that usually following a trauma. It was observed that the tendon appeared to be smaller and smaller as the exploration was carried downward from its point of upper attachment. The tendon was relaxed and appeared to lie loosely above the irregular musculofibrous mass.

It was apparent that there was not a reasonable possibility of disentangling the irregular muscular mass in the lower part of the biceps region. Another observation that was of considerable interest was that the tendon of the short head was much heavier than usual, and appeared to be largely muscular in character. It was believed that the short head side of the biceps was attempting to take over the function of the practically destroyed long head side.

Since there was no dislocation of the tendon that would appear to make it wise to undertake a radical transplantation of it, and since it appeared to be impossible to disentangle the irregular mass fixed by traumatic reaction in the lower left biceps region, it was decided to shorten the long head tendon as much as possible, and to suture it to the short head tendon, at the same time placing sutures in the distorted musculofibrous mass in such a way that there would be a lifting-up effect when the sutures were tied.

There was no particular postoperative difficulty, and the patient was temporarily discharged a week after the operation. He was seen several times after that, and was kind enough to say that he thought that the arm upon which operation had been done was stronger and more comfortable. The patient left our service after a few weeks. In the meantime, we had not done anything at all in connection with the mass in the right lower biceps region.

As we have indicated, we are quite strongly of the opinion that in the case of this particular individual, and individuals like him, with perfectly normal muscular development and good health, there is a predisposition to rupture of the muscles due to strain and overwork. In other words, this man, 5 feet 2½ inches tall and only 137 pounds in weight, was trying to do the work of a strong man, but he did not have the physique necessary for such work. With such a conception of the situation, we are distinctly of the opinion that substandard physique, regardless of how normal the patient may be in ordinary respects, is a definite predisposing cause.

The patient whose case we have just reported came to us in 1934. In looking over the literature we were fortunate enough to find a most remarkable and instructive article by Edgar L. Gilcreest, of San Francisco, published in the *Journal of the American Medical Association* in 1925. He had done the "ground work" for us, and it was only necessary for us to sit down, read the article, look at the drawings and make a diagnosis.

We learned from that article that Petit is credited with the first report of a case of rupture of a muscle in 1722.[2] Then for nearly 150 years nobody seemed to be interested in the subject.

In the United States, W. W. Keene gave some impetus to the study in a report of seventy-two cases (presumably of the biceps), published in the *Annals of Surgery*, May, 1905.[1]

After another apparent lack of interest, occasional contributions appeared in European publications about twenty years later, and about that time Gilcreest and his associates entered the arena. Their contributions have been voluminous and constructive. Their articles have appeared in practically all the important surgical publications of the country, and in connection with them there are unmistakable evidences of industry, tenacity of purpose, erudition and fairness. In his earlier articles, and since then, he has mentioned A. W. Meyer, Palo Alto, California, and many others who with him are interested in this entrancing subject. A most extensive and exhaustive article, entitled "Unusual Lesions of Muscles and Tendons of the Shoulder

Girdle and Upper Arm" by Edgar Lorrington Gilcreest and Piero Albi, San Francisco, was published in *Surgery, Gynecology and Obstetrics*, May, 1939. It contains a tremendous fund of information, and both Dr. Gilcreest and his associate, Dr. Albi, are to be most heartily congratulated.

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# PATHOLOGICAL CHANGES INDUCED IN TENDONS THROUGH TRAUMA AND THEIR ACCOMPANYING CLINICAL PHENOMENA*

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THE function of a tendon is a purely passive one of transmission of tensile stress produced by the motor action of muscle. This function, at the same time, demands a gliding of the tendon either on or within the surrounding tissues, or within its synovial sheath. We know of no single metabolic function whose activity is dependent on or concerns the tendon itself, and conversely, no disturbed metabolic processes are known to produce alterations in tendons, except amyloid disease, ochronosis or hypercholesterinemia.

In order to appreciate pathologic alterations of tendons, we must have a clear concept of their normal histology. A tendon is composed of parallel fibers of collagen held in compact bundles partly by an encircling epitenoneum. Since Ranvier[1] we have talked of tendon corpuscles as tendon cells, and numerous authors have investigated the part played by these corpuscles in the growth or regeneration of tendon.[2,3] The results of these investigations are contradictory and all assume that tendon cells are particular and specialized cells related only to tendon.

Histologic and pathologic investigations (carried on in the Surgical Laboratory of the Stanford University Medical School) reveal some interesting facts bearing on this question. If one studies fresh tendon tissue of the mouse, in which the extensor tendons of the toes can be examined in their entirety from muscle-tendon junction to their attachments, the tendon cells lie apposed in parallel rows, with oval nuclei when seen in full face, much as a beaded string, seen in profile. These "tendon cells" lie between the closely packed parallel collagen fibrils, and on close examination can be seen to enclose or line tiny canaliculi or longitudinal spaces. In certain preparations, I have sometimes been able to demonstrate their direct lateral connections with blood vessels traversing the tendon in an oblique or transverse direction deep within the tendon. The

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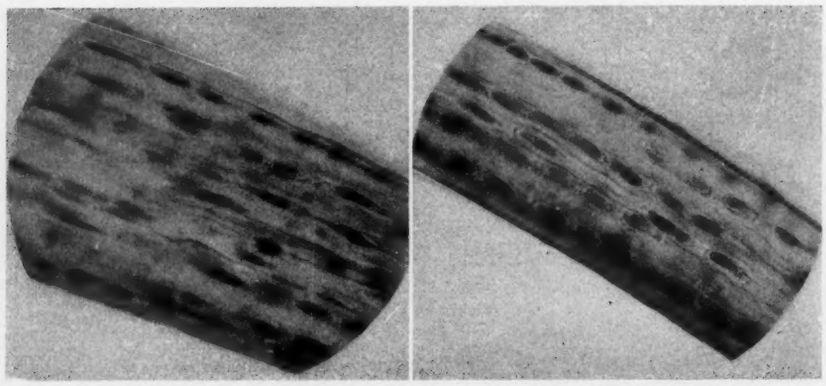

FIG. 1. Glycerine mounted mouse tendon—Delafield's hemotoxylin stain. The photograph to the left near the upper border of the tendon shows profile appearance of the tendon spaces with the nuclei bead-like in arrangement, and the opposite fine border of the lumen. In the microscopic photograph on the right, the full face of the cells are apparent. The continuity of the structure from cell to cell can be observed.

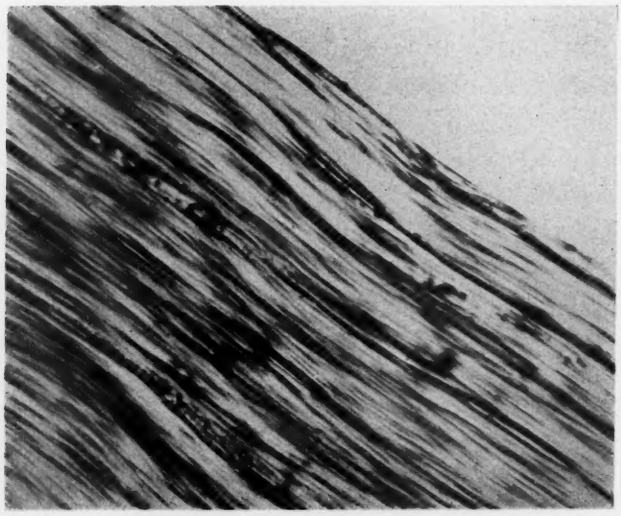

FIG. 2. Photomicrograph × 900. Fresh mouse tendon—supravitally stained with neutral red. The collagen fibers do not take the stain. The cells of the tendon spaces show fine granules of the vital dye distributed throughout their cytoplasm as shown by the stippled or dotted areas in the tendon. Cell and nuclear outlines are not shown above. With the light stopped well down, through the microscope, the relation of cell and nucleus to the granules is easily made out.

same structures can be seen in paraffine sections of dog or human tendon stained with borax carmine. Figure 1, a glycerine mounted mouse tendon stained with Delafield's hemotoxylin, illustrates these characteristics.

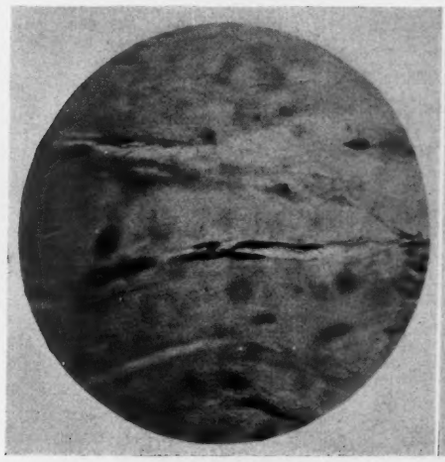

FIG. 3. Photomicrograph of human tendon (sublimus tendon of index finger). Paraffin embedded section. Hematoxylin and eosin stain × 600. The central part shows a portion of a tendon space.

FIG. 4. Photomicrograph of dog tendon × 600. Hemotoxylin and eosin stain. The tendon had been divided two weeks previously. This particular photograph was taken from the tendon proximal to the tendon end which was covered with a cap of granulation tissue springing from the epitenon. The central tendon space of the photograph is enlarged and contains red blood cells.

When one uses fresh tissue and the supravital dye technic of Warren and Margaret Lewis,[4] one finds that these tendon cells take the neutral red dye in the same manner and with the distribution of granules that Warren Lewis showed to be characteristic of endothelial cells. (Fig. 2.) By this technic and by comparison with known tissue cells, one can demonstrate that these cells are not fibroblasts, cartilage cells or macrophages. In addition, one can refute the view held by some investigators in the past, that they are nuclei of a continuation of the muscle sacrolemmal sheath. Their reaction to vital dyes, their arrangement in continuous rows and the fact that they line spaces, suggest that they are endothelial in nature. That they are continuous with the endothelium of blood vessels in normal tendon, and that they may open up into blood sinuses of granulation tissue in severed or injured tendon, can be seen in carefully prepared specimens. (Figs. 3 and 4.)

The tissue culture work of Margaret Lewis[5] has shown that collagen fibrils are laid down by the activity of living fibroblastic cells, but since the fibrils themselves become extra cellular, they do

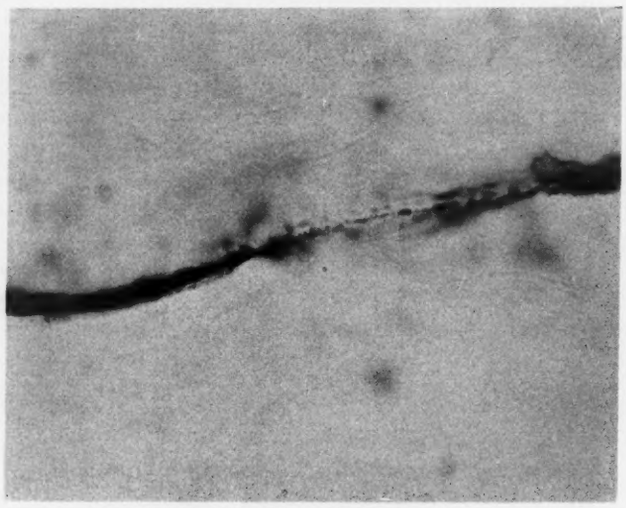

FIG. 5. Rat tendon—fresh glycerine mount × 900. Granules of Prussian blue shown in the tendon space deep within the tendon.

not necessarily maintain contact with their parent cells, and in a sense, loose their living properties. In vitally stained tendons, fibroblasts are conspicuously lacking except in the outer ensheathing fibroelastic layer of epitenon. We can regard tendons then as composed of compact parallel bundles of inert collagen fibrils, encircled by fibro-elastic tissue and traversed longitudinally by extremely fine capillary spaces, which probably under normal circumstances contain plasma but no cellular elements of the blood.

Additional evidence for this concept is furnished by the following experiment: One-half cc. of a 50 per cent solution of iron and ammonium citrate was injected into the tail vein of a white rat. After an interval of twenty minutes, extensor front paw tendons were removed from the anesthetized animal and placed for ten to fifteen minutes in a 2 per cent solution of potassium ferrocyanate. A single small tendon was then placed under a cover slip in acidified glycerine (1 per cent hydrochloric acid). The Prussian-blue reaction of iron could be found in the tendon spaces. (Fig. 5.) With formalin fixed paraffin sections counterstained with borax carmine, it was possible to show the Prussian-blue reaction in the spaces of the tendon of such injected animals. The lining cells of the spaces were found to undergo a blue staining with brilliant azure granules within

the nuclei. These preparations were obtained with difficulty because of the solubility of iron ammonium citrate in aqueous fixatives, while alcohol fixation precipitated abundant long needle like crystals in the tendon disrupting its structure. (The crystals failed to stain with Prussian-blue.) It should be noted that following injection, the iron could be identified only in the kidney, liver, spleen, tendon, lung, and on one occasion in the capillaries of the perirenal fat. Cartilage, muscle and bone showed no similar reaction. It is hoped that further studies of this problem may subsequently be reported in detail.

German investigators[6] showed not only the inextensibility and lack of distensibility of tendon, but also found that tendon or fascia on dehydration looses no length, but diminishes in width or diameter, and on accurate weighing, loses little moisture. Moisture is necessary for the pliability of the tendon fibers, which otherwise become like dry rawhide. One might assume that the fine channels of the single-layered, endothelial cells in the interstices of the tendon bathe the collagen fibrils with plasma, thereby maintaining their pliability and having an internal lubricating effect, rather than conveying nourishment and removing metabolic products.

The microscopic blood circulation of living tendons in the rat was studied by means of brilliant carbon arc illumination of the exposed paw extensor tendons in the anesthetized animal (nembutal intraperitonealy). Mineral oil covered the exposed area, increased the clarity of microscopic picture and served to delay thrombosis of the vessels. With such preparations, by reflected light rather than by transillumination, each tendon was seen to be accompanied by arterial and venous vessels. These in turn send S-shaped loops across or beneath the tendon, and capillary penetration of these fine tendons was clearly shown. The capillary flow was seen to be rapid, intermittent, and reversible in direction. Section of the sciatic nerve did not open up the tendon spaces to a capillary flow of red blood cells.

With such a conception in mind, we might more easily explain the pathological changes that are found in tendon injuries or disease. First, that major injury of tendons is necessary to produce pathological changes, a sort of "all or none effect." No one has been able to show that normal replacement of tendon collagen fibrils takes place during adult life in a way similar to the constantly occurring growth and shedding of epithelial cells of the skin and mucous surfaces.

Severed tendons heal and unite, when sutured, by granulation tissue with scar formation. Under the influence of tissue tension and tensil stress, the collagen fibers of such granulation scar tissues

FIG. 6. Photomicrograph—Hematoxylin and eosin × 100. Longitudinal section of tendon callus. The nuclei tend to orient their long axis parallel to the direction of the tensile stress.

tend to become arranged into parallel bundles scarcely distinguishable from normal tendon and function admirably, but the tendon cells do not consolidate the tendon callous.

Tendon rupture in sheathless tendons may be followed by spontaneous repair with lengthening of tendon and loss of mechanical efficiency. This spontaneous repair at a distance differs in no way from the repair following suture. (Figs. 6 and 7.) Such repair is by granulation tissue from the surrounding vascular paratenon structures. The tendon cells, as a specific type of cell, do not reform the tendon, but the developing scar tissue under tissue stress lines up the developing collagen fibrils into parallel bundles.

CASE 1. J. F. S., age 40, a traveling salesman, was injuried in an automobile accident January 7, 1940. He suffered a cerebral concussion, frac-

tured ribs, 6th, 7th and 8th, right, and contusion of dorsum of right hand with several small glass cuts on same hand. Convalescence was short and without evident complication. During the first three weeks all movements

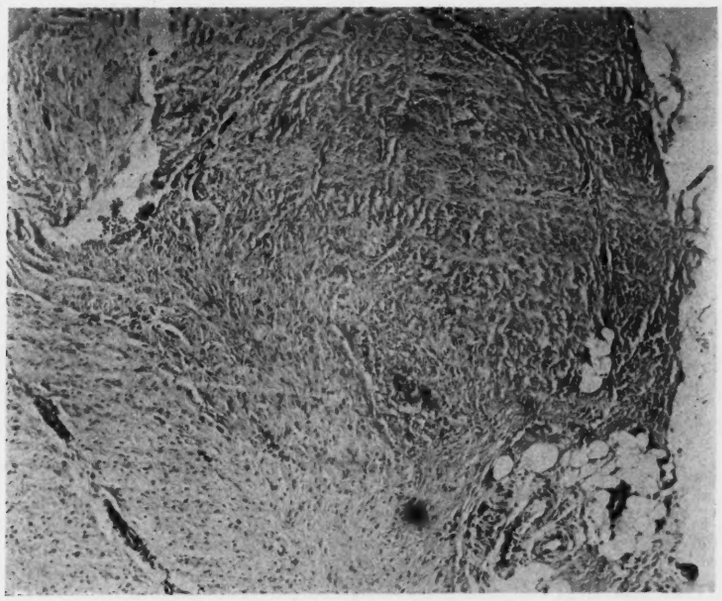

FIG. 7. Cross section photomicrograph of the same tendon callus. The tendon-like structure is well illustrated in the two photographs. The blood vessels seem to divide the callus into poorly formed bundles of fibers.

of the fingers of the right hand were perfectly normal. An *x*-ray of the hand and wrist revealed no fracture. After three weeks, a small, subcutaneous nodule became apparent over the dorsum of the index finger knuckle in the neighborhood of one of the healed glass cuts. A week later, a similar lozenge-shaped, subcutaneous nodule appeared near the wrist, overlying the index metacarpal. Both nodules moved with finger motion, and as time passed they became more prominent and began to be painful. A "drawing sensation" was complained of, and flexion of the finger increased the feeling of strain which gradually became more annoying to the patient.

On March 7, 1940, operation was performed under local anesthesia. The lozenge-shaped nodule was found to be the proximal end of the severed extensor digitorum communis tendon of the index finger. The distal end was found overlying the metacarpal phalangeal joint on the radial aspect of the knuckle. The intervening tissue between the two tendon ends consisted of grey, pearly, opaque tissue of dense, tough consistency without visible fibers, and which surrounded the proximal tendon end like a glove. This tissue was continuous to the distal tendon stump, a distance of 7 cm., and also ran over to the tendinous vincula and mesotendon of the common extensor tendon of the midfinger, while towards the radial side of the hand it became thin and filmy. The tissue was readily peeled from the tendon

stump by sharp dissection. The entire "tendon callous" was excised in one mass. No other evidence of proliferation from the severed tendon ends could be made out. The tendon stumps were sutured accurately with black silk, the subcutaneous tissue and skin approximated with similar sutures. The hand and wrist were placed in slight dorsiflexion of the wrist, with moderate flexion of the midphalangeal joint, and with not quite complete extension of the metacarpal phalangeal joints.

The splint was removed in three weeks. Return of finger and wrist motion quickly followed, and the patient was discharged on April 26, 1940, with complete restoration of function without pain or tenderness.

The typical tendon callous, whether after suture or following separation of tendon ends and repair at a distance, as in this case, does not grossly resemble tendon tissue, but under the microscope paraffin embedded stained sections bear a striking resemblance to tendon structure. (Figs. 6 and 7.)

Secondly, when injury to tendon occurs, short of severence or rupture, it is the fibrovascular epitenon, the vascular mesotenon, the paratenon or vincula, bearing blood vessels, which respond with pathological changes, rather than the tendon collagen fibrils themselves.

Traumatic stenosing tendovaginitis of De Quervain may follow a single blunt injury, as in the following instances:

Case II. L. M., age 29, a male house boy, while scrubbing the kitchen on February 9, 1940, with a circular motion of the right arm he struck the radial side of the right wrist against a corner of the kitchen table leg. The wrist continued to be sore and tender, and the patient experienced difficulty lifting with this hand. Examination on February 12, 1940, showed swelling of the radial side of the wrist with obliteration of the anatomical snuffbox of the thumb. The tip of the radial styloid was exceedingly tender on pressure. The patient had pain in this area on abduction of the thumb against resistance, and on passive hyperadduction and flexion of the thumb with the thumb held in this position by closing the fingers, ulnar adduction of the wrist was excruitiatingly painful. Physical examination revealed no other abnormalities, and there was no evidence of urethritis. The patient had no fever and the white blood count and differential count were normal. The sedimentation time was rapid. The patient was fitted with a moulded leather, re-enforced splint, holding the thumb in abduction and preventing motions of wrist and thumb. The patient, being relieved of all distress, continued to work.

The splint was discarded on March 26, 1940, but by April 2, 1940, the pain and tenderness recurred. By April 4, 1940, "snapping thumb" of the distal joint appeared. Operation for traumatic stenosing tendovaginitis was carried out on April 6, 1940, under local anesthesia.

The tendon sheath of the extensor brevis and the abductor longus were first exposed and incised. A probe was readily entered into the tendon sheath without finding stenosis. On incising the sheath, one found there was definite thickening which was apparently extension of the dorsal carpal ligament, but on the outer surface it had a grey, brownish yellow appearance, as if old blood pigment were in the tissues. On opening the sheath completely, one found the inner surface of the tendon sheath moderately injected, and the mesotendons of both tendons were definitely engorged. The tendons ran through what appeared to be a bony groove with high, sharp walls. This felt perfectly bony hard to touch, but after the tendon sheath and its ligamentous thickening was dissected further, this apparent bony wall was found to be indurated tissue and attached to the periosteum. This was excised for section. The tendon sheath of the extensor pollicus longus was then exposed and the tendon was found held tightly gripped by a markedly thickened dorsal surface of the tendon sheath, and one could not place a probe from the lower free portion of the sheath beyond this obstruction. In addition, on voluntary or passive movements of the terminal phalanx of the thumb, one found there was a trigger tendon present, and before fully opening the sheath, on movement of the terminal joint, one saw a "jumping catch" of the tendon beneath the tight scarred band and a rotary twisting of the tendon as well. On fully opening the sheath, one cut through a gristle-like tissue on the anterior border, and exposed the synovial surface of the sheath which was more than moderately injected. The tendon showed signs of inflammation and on its anterior surface, at the distal anterolateral portion of the mesotendon, was a small protuberence, brown, reddish-grey in color, 1½ to 2 mm. in diameter, which felt perfectly hard. This was carefully dissected from the tendon. The underlying tendon looked seared and brownish, but there was no apparent gross defect in its fibers. It was now noticed that the tendon moved in full range of motion without any rotary or twisting torsion. An apparent bony groove was again found about this tendon, and as before, on lifting up and dissecting forward the sheath itself exposed the underlying tissue as dense, hard and gristle-like. This was excised. The anterior portion of both tendon sheaths were completely excised, the subcutaneous tissue and skin closed with interrupted sutures of fine silk after suturing the deep fascial structures over the tendons. The wound was dressed with tincture of benzoin gause and sterile gause dressings. Cultures of the synovial fluid were negative.

The patient returned to work on April 18, 1940, and has remained symptom free. He was last observed on May 2, 1940.

The edematous and vascular synovial lining of the tendon sheath is shown in Figure 8. The walls of the bony-hard gutter through which the tendons coursed, are shown in Figure 9. Instead of bone or cartilage, it is a compound of fibrous tissue bundles separated by

edema and containing numerous, large vascular sinusoids. The hard nodule on the surface of the tendon, and which was responsible for the development of the trigger thumb proved to be organizing granulation tissue.

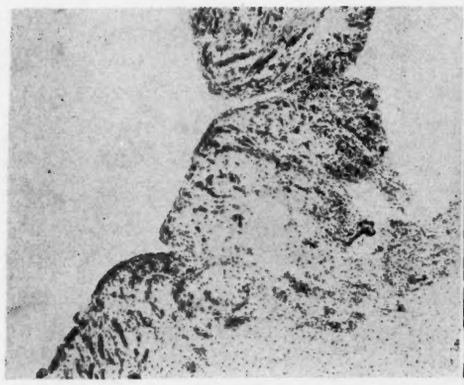

FIG. 8. Photomicrograph × 100. Hemotoxylin and eosin. This synovial lining shows the edema and vascularity of the typical case of stenosing tenosynovitis.

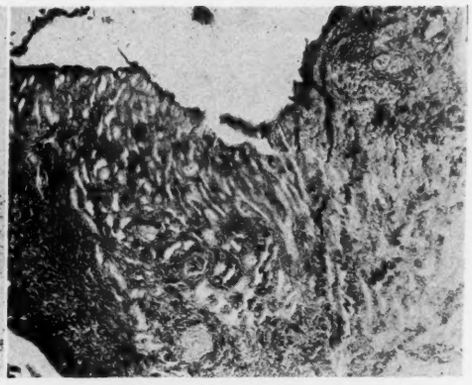

FIG. 9. Photomicrograph × 100. Van Gieson's stain. Considering the marked vascularity of the edematous fibrous tissue, (2 months after injury) it is difficult to reconcile such an appearance with the bony-like consistency found at operation.

CASE III. L. L. The last week of March, 1939, the patient, age 40, a shop girl, struck the inner aspect of the right ankle against the sharp corner of a box. The stocking was torn, and the ankle, at the site of contusion, became black and blue. The patient treated the lesion herself with hot compresses but no improvement was evident. The initial swelling subsided to be followed later by localized swelling, tenderness and pain on weight-bearing. Examination on April 4, 1939, revealed definite localized edema beneath and posterior to the internal malleolus of the right ankle. There was marked tenderness in this area. Eversion of the ankle and inversion against resistance, as well as forced dorsiflexion, produced pain. (Strapping of the ankle gave only partial relief.) *X*-rays of the ankle showed the bony structure to be normal. On April 28, 1939, the area was injected with novocain; the posterior tibial tendon sheath was injected with air. Radiographs showed the tendon sheath well outlined and apparently narrowed beneath the malleolus.

Operation, May 12, 1939, for traumatic tenosynovitis and stenosis of the posterior tibial tendon sheath was performed under local anesthesia. On exposure of the sheath, a tense bulging area with thin walls was found distal to the dense fibrous retinaculum beneath the malleolus. Pressure on the bulging sheath reproduced the patient's previous pain. On incising this area of the sheath, brownish, straw-colored, clear mucinous fluid was evacuated. (Cultures of the fluid were negative.) The tendon in this area

was bulbous and fusiform over a distance of 3 cm. The sheath was incised proximalward for 6 cm. and found to be engorged, with a velvety red appearance, the mesotenon markedly swollen with pannus-like projections

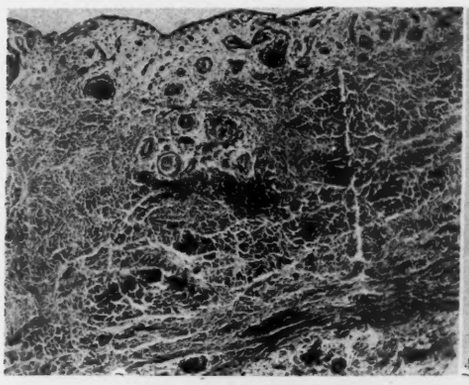

FIG. 10. Photomicrograph × 100. Hemotoxylin and eosin. The marked vascularity of the synovial layer gives rise to a velvety, deep red appearance in life. The fibrous character of the outer layer of the sheath is here more marked than is usually encountered.

FIG. 11. Photomicrograph × 100. Hemotoxylin and eosin. Such villi, brilliant deep red in gross appearance, are found to be extremely vascular with an interstitial edema. The perivascular round cell accumulation near the base is an infrequent finding.

on the under surface of the tendon, and fine villi were found both on the inner surface of the sheath and projecting from the mesotenon.

The bulbous area of the tendon was dense-white without the mother of pearl sheen of normal tendon surface. An elliptical longitudinal section of this area was excised and the defect closed with fine silk sutures which restored the normal diameter of the tendon.

A narrow strip of tendon sheath was excised and the larger villi removed. The lower half of the sheath was retracted and the sheath incised through its length on the inner, deeper surface down to the loose areolar layer. This allowed the sheath to be closed without constriction and with the preservation of a tendon retinaculum.

The patient returned to her work on June 14, 1939, and has continued without recurrence of difficulty.

Figure 10 illustrates the thick-walled, fibrous sheath of the stenosed area with an edematous and vascular synovial lining. A characteristic villous synovial granulation is shown in Figure 11. These richly vascular, edematous villi arise from the synovial sheath or the mesotenon. The late reaction of the tendon itself to the trauma is shown in Figure 12. Here one sees numerous vascular sinusoids of an edematous granulation tissue lying between and invading the parallel collagen bundles of the tendon proper.

While the vascular tissues of the fibro-osseous canal may in many instances show the greatest tissue changes, the tendon through its sheath or epitenon, or by vascular changes within the center of the tendon itself, in these instances demonstrate the result of injury.

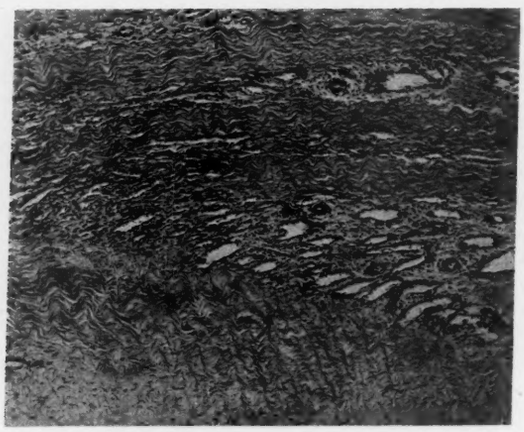

FIG. 12. Photomicrograph × 100. Hemotoxylin and eosin. Deep within the bulbous tendon of changed gross appearance, this area was found seven weeks following injury; edematous granulation tissue having large vascular sinusoids spread apart and distort the tendon bundles.

"Tenosynovitis fungosa"[7] may follow repeated blunt trauma. In this condition which occurs in sheath tendons (in each instance which I have encountered the extensor tendons of the fingers beneath and at the distal edge of the dorsal carpal ligament were the site of this disease) the granulation tissue apparently develops in mesotenon or the vincula and by virtue of constant irritation through repeated frequent motion, the granulations continue to develop. The vascular granulations invade between the tendon fibrils, and by vascular erosion lead to fraying of the tendon under tensile stress and to eventual rupture. Whether the spontaneous rupture of the long head of the biceps falls in this class of change, I have not had the opportunity of ascertaining. Mechanical attrition with fraying of tendon, such as occurs in the supraspinatus and other tendons and pointed out long ago by Mayer[8] may go on for months or years until acute symptoms manifest themselves in an attack of "acute subdeltoid bursitis."[7]

In essential ideopathic hyperchloresterinemia deposits of unsaturated fats and sterols may accumulate in para and mesotenon about the small capillaries producing xanthomatous tendon tumors. While this process is a disturbance of general lipoid metabolism, it is

in the vascular bed of the tendon extension apparatus that the lipoid deposit takes place. The tendons are involved secondarily by adhesions and vascular erosion from the lipoid granulomatosis. Location of such xanthomas may possibly be initiated by trauma.[2]

## CONCLUSION

Tendons possess an internal endothelial lubricating apparatus maintaining the pliability and suppleness of the moving part. The collagen fibrils may be considered as inert, extra cellular material. They do not participate in metabolic processes, and are incapable of response to irritation or trauma, except that of mechanical fraying or rupture.

Trauma to the tendon-traction apparatus must involve the vascular structures to make a response towards healing possible. The attempt at healing may produce clinico-pathological phenomena arising from interference with free unimpeded tendon motion, or from vascular erosion of tendon fibers. In this manner, a single or repeated tendon injury may call forth diseased states which may become chronic, and at first glance, seem unrelated to the initial injury.

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## DISCUSSION OF PAPERS OF DR. DOBBIE AND DR. HOWARD

Henry C. Marble (Boston, Mass.): The hour is late and the body is weak, so I will make my discussion brief. I hoped that I might not say anything, but I cannot again let efforts at "post-hope" reasoning go unchallenged.

May I call your attention to just two facts: The most commonly injured part of the human body is the hand, probably ten times as often as any

other single part of the body. I repeat: The human hand is probably injured ten times as often as any other part of the body.

In the registry of bone sarcoma maintained by the American College of Surgeons, osteogenic sarcoma of the hand is authentically reported in one case, and that is my case, and the patient did have it. I am sorry that that is true because then my story would be 100 per cent, but if we think of the tremendous number of traumas that occur to the hand, and we think of the registry of bone sarcoma, there is only one authentic osteogenic sarcoma of the hand reported, and it reduces it to a very small possibility of trauma.

Next, I recently looked up the cases of fractures which we have known and reported as trauma, not minimal traumas like slaps on the wrist and kicks in the shin, but real trauma, and in the Massachusetts General Hospital's series of fractures, we have not a single malignancy following an injury except one. We had one case of Paget's disease which subsequently had a fracture and subsequently had a sarcoma. So let us reason the matter of the relationship of malignancy to trauma, from trauma to malignancy, and not from malignancy to trauma, and then maybe we will have better results.

Now, the next matter that I have to discuss is the matter of the preservation of tendon function, and I just thought as I listened to that excellent paper, that, after all, genius is only the capacity for infinite pains. In the matter of constructing a hand as he showed in the pictures, I have only admiration.

I would go him one further and say that at one time I had a man who had a complete amputation of all four fingers and the thumb at the metacarpal phalangeal joints and as a result of about a year of struggle, and as the result of several surgical operations, I digitalized the metacarpal bone of the thumb to such an extent that the patient could hold a pencil between the thumb and the index metacarpal bone, and the patient is now earning a living. He can write; he can feed himself; and that little amount of motion which he has between his thumb and index finger, he believes justifies several anesthesias and an awful lot of hospitalization.

I believe that notoriously artificial hands are inadequate and unsatisfactory and any degree of function which we can have even to a centimeter between two opposing parts of the hand, is worth while and should be obtained.

That was an excellent presentation. The matter of grafts as he puts them on was beautifully demonstrated. I confess that I use a rope graft more than I do the two-ended graft flap such as he showed. I like the rope graft, and, after all, it is the weapon you like to shoot with best that kills the most fowl.

I think sometimes we can hasten matters if early in the injury we proceed to prepare the graft. I mean prepare the rope and have it ready to put on by the time that the injured part of the hand is clean and is ready to receive its graft. If we have previously prepared the rope on the side and put it on, sometimes we can save two or three valuable weeks—that is, to

synchronize our surgery—and that is a good word, is it not, "synchronize" our surgery?

The avulsion of the lower tendon of the biceps interested me because I have written letters to Dr. Dobbie on that subject. The matter of avulsion of tendons from bone is intriguing. Our results, I think, vary with our ability to diagnose them. The two cases that I have seen of rupture of the lower insertion of the biceps were both easily diagnosed. The results were good.

The other end of the biceps tendon is more difficult to diagnose and the results are not quite so good, but thereafter when we have had ruptures of the supraspinatous muscle, which are difficult of diagnosis, and the operation has been postponed, our results have been poorer.

I was glad to hear Dr. Dobbie tell about his results as to insertion of the lower end of the biceps into the soft tissues, and I think it sort of discourages me because, personally I like to dissect the antecubital space. I think it is intriguing. There are large vessels there, and Dr. Brewster used to say, "Don't ever worry about anything you can see; it is the things you can't see that you should worry about." In the bend of the elbow, you can see, and the anterior approach to the elbow is interesting. We find the great vessels and can easily turn them aside, and then the supinator muscle, and in the inner wall of the great supinator we find the radial nerve and the muscular spiral, and pull it out, and below it is the insertion of the biceps; and, by supinating the arm, the bicipital tuberosity comes up to this line, and with a simple dissection we can go around the radius and a piece of fascia lata makes a good anchor. I like to do the operation, and I am sorry they do so well who do not do that operation, but I suppose it is correct.

It is a very interesting piece of work and a very useful piece of work. The cases that I had were all over fifty, middle-aged workers who returned to their usual work after operation.

Dr. Dobbie did not say (which I think is important) that if the patients are splinted in supination, I believe their power of supination will ultimately be better.

On the last presentation, read by Dr. Howard, I have little to say. I think it is a grand bit of work on the pathology and histology of tendons. To me it just pointed one lesson. Recently I have seen come from a great distance, two patients. The second patient had on the flexor surface of his fingers two large tumors, each about 2 cm. long and 2 cm. wide, and elevated maybe a centimeter and a half or a centimeter, which obstructed the function of the hand very materially—all of this following tendon suture. I thereupon explored these tendons under novocain and when we had opened the tumor, we found that it was a foreign body cyst, and having removed several large pieces of silk, and nothing more, the cysts were reduced in size and the patient proceeded to make a happy recovery.

Why we feel the need, when we repair tendons, of going and borrowing a canal-boat hawser, I cannot quite understand. The tendon, as Dr. Howard

has pointed out, is a delicate structure, and will heal if given half a chance, and by much simpler methods than we have used in the past. By approximating the ends of the tendons with very simple sutures, very gently done, we can approximate the delicate structures, as he has shown you in the lantern slide, and I think very, very satisfactory results can be obtained.

I think he is to be particularly congratulated upon the thoroughness of his work and the thoroughness of his study of the literature.

D. C. PATTERSON (Bridgeport, Conn.): Dr. Marble has so ably discussed these papers that there is very little left to be said. The papers and discussion have been most instructive and interesting.

Dr. Howard did mention one thing, though, that I should like to call to your attention, and that is the matter of DeQuervain's disease. He said, I believe, that he had seen it develop from a single trauma. We have had some little experience with this condition but I have never seen it develop fron a single trauma. We have always thought that it was due to repeated traumas. To those of you who are not familiar with the condition, I would like to mention something about it because it is, to my mind, the most satisfactory disease to meet that the human body is afflicted with, because diagnosis is generally easy, and the result is practically a 100 per cent cure.

The condition was first described by DeQuervain in 1895 or 1896, as a narrowing of the tendon sheath that transmits the extensor brevis pollicis and the abductor longus pollicis, through a groove in the styloid process of the radius. If you will put your thumb in your hand and close your fingers over it and sharply ulnar adduct your hand, you will get a pain over the radial styloid which is perfectly typical of the pain these patients suffer most of the time.

Kocker gave the condition the name of stenosing tenovaginitis, but it is generally known as DeQuervain's disease. There are very few papers in the American literature on the subject, only four or five, I believe.

The pathology is a thickening of the tendon sheath with, of course, that part of the carpal ligament which goes over it. It is most frequently found in women. Out of the 145 cases that Snyder collected, mostly from foreign literature, 114 were in women and the remainder in men.

We have had more than a dozen cases of this disease. They occurred mostly in men who were working at tasks that required pressing with their thumbs, such as on a grinding machine or on a buffer. There was one woman that had been working placing a rubber ring over the end of a brass pipe. Her employers had a rush order on this piece of apparatus and she had performed that operation five hundred times in one day. That night she had severe pain in both wrists and was treated with heat and massage. Baking, strapping, etc., were carried out for about a month without any benefit whatever.

The symptoms are: pain over the radial styloid and interference with abduction of the thumb. The pain may extend up the arm or into the thumb. The tenderness is absolutely localized to a small spot right over the

radial styloid. There is no tenderness anywhere else. These patients become disabled, as they gradually lose the strength in the thumb and drop articles. That will go on until operation has been performed.

The operation and cure of the condition is so simple that I do not think conservative measures should be considered at all. There have been some cases reported of cures within four to six weeks in a plaster cast, but nothing has ever been said about recurrences in those cases. I have never seen a cure by nonoperative treatment. The operation can be done under local anesthesia, with a two-inch incision over the radial styloid and, as Dr. Howard pointed out, the annular ligament with the tendon sheath will be found tremendously thickened. We have found it at times at least a quarter of an inch thick and sometimes almost cartilaginous.

The tendon sheath is incised, which allows free passage of the tendon. The wound is sutured and a simple dressing applied. No splinting is necessary. Patients are allowed to use the thumb within a few days, and the period of disability is never over two or three weeks and, as I mentioned before, the cure is practically certain in 100 per cent of the cases.

TORR WAGNER HARMER (Boston, Mass.): I should like to present the only case of avulsion of the lower bicipital tendon which has come under my care. The story is as follows:

November 30, 1938: G. D. L., was a powerfully built stationary fireman of forty-seven, weight 190. Several hours previous, while attempting to lift the rear end of a Ford car, he felt a snap in the front of his right elbow. There was much tenderness in this area and no contraction of the biceps muscle when attempting to flex the forearm. It was believed the distal bicipital tendon had been torn off the muscle belly. Preparations were started for fascial repair.

December 1, 1938: The radial nerve was exposed above the elbow and followed into the antecubital space to its division into the posterior interosseous and radial cutaneous branches. The biceps tendon was found avulsed from its attachment to the bicipital tuberosity. The tendon was found coiled up under the distal end of the muscle belly. When straightened, it was about four inches long. The bicipital fascia had been completely torn. Retraction of the supinator longus showed that the tendon had been avulsed from the bicipital tuberosity of the radius. There was not even a fringe of tendon remaining. Reattachment was regarded as undesirable because of inaccessibility, and the possibility of limiting pronation and supination. Accordingly, the tendon was split lengthwise, each half was threaded on a large Gallie needle and woven into the attachment of the brachialis muscle, one half being introduced from the medial side and the other half from the lateral side. A thong of fascia from the left thigh was loosely whipped about the upper end of the tendon to prevent its splitting into the muscle, then loosely woven through the split biceps tendon down to the new attachment into the brachialis insertion. It was here woven into this attachment.

Primary union was secured and the patient discharged from the hospital on the tenth day. Four weeks after operation there was good flexion of the forearm from a point just beyond a right angle. Nine weeks after operation, extension of the forearm lacked twenty degrees; flexion was complete with excellent contraction of the biceps. The man returned to work as stationary fireman, stoking several fires in a large building, in twelve and a half weeks.

NELSON J. HOWARD (closing): I want to thank Dr. Marble and Dr. Patterson for their kindness and their discussion. I do not know whether I should ask Dr. Marble in public what his reference to the thoroughness with which I covered this, meant, whether it was a gentle form of sarcasm or not. I sent him a manuscript and did not include a bibliography, so I have occasion to believe I am being taken for a ride.

While certainly many instances of DeQuervain's stenosing tendovaginitis do follow repeated trauma or follow Colles' fracture, in my experience I have had definite instances in which they followed single traumatic incidents. The case which illustrates it best is that of the Filipino boy scrubbing a marble floor, and as he went along the edge of a sharp-cornered wash stand, with metal corners, he bumped his wrist into the sharp corner. He had pain, increasing disability, and came to see me only two days afterwards, and I considered it would respond well to conservative treatment. I splinted it for a matter of three weeks with no improvement, and continued the splinting for another three weeks with no improvement. Operation was carried out and not only did we find a stenosing tendovaginitis of both tendon sheaths, but also involvement of the extensor pollicis longus and the abductor pollicis longus, and during the last week, the week the splint was removed, we found he had developed a trigger thumb on extension and flexion of the distal joint of his thumb. Within the stenosed sheath of the extensor pollicis longus I found a definite mass on the surface of the tendon, apparently where the major initial injury had taken place. This was separated, leaving the tendon normal in appearance, and on microscopic examination the nodular mass, which felt definitely hard and cartilaginous, proved to be dense granulation tissue.

Now, DeQuervain's stenosing tendovaginitis may be treated conservatively, if you get it early. In some cases I have had simply a molded leather splint made for the patient, with the thumb in position of grasp, the splint on the thumb extending clear out to the tip of the thumb, and within six weeks of such splinting, wearing it day and night, the patients were all continuing at their work. None of them were industrial cases. They were then able to leave the splint off, and some of the cases have now gone as long as five years, and the latest one two years, without recurrence.

Their is a cartilaginous consistency of the base of tendon sheath, grooves or tunnels, and if you remove that material, you will find it is neither cartilaginous nor bony. It is not periosteal reaction but is dense, infiltrated granulation tissue.

# FRACTURES OF THE UPPER END OF THE TIBIA WITH LATERAL DISPLACEMENTS

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SEATTLE, WASHINGTON

FRACTURES of the upper end of the tibia are quite common and have been a rather difficult type of fracture to treat especially as to obtaining a good functional result. The poor functional result is due in most cases to one of two conditions and sometimes both, namely, extensive damage to the ligamentous structures in and about the joint or to an inadequate reduction of the fracture. It is frequently the case that a very adequate and satisfactory reduction has been obtained but an inadequate fixation has been applied to maintain the reduction. Then again a good reduction has been obtained and too early weight bearing has been allowed permitting a recurrence of the deformity.

Sometimes it is very difficult to determine the degree of the consistency of the callus, and then of course, a too early weight bearing results in a recurrence of the deformity and the common end result is a weak, unstable knee with a knock knee deformity. In my experience when such an end result is obtained, manipulative or even open reduction for the replacement of the displaced fragments has not given very satisfactory end results, nor does the wearing of a brace seem to be of any help.

Such type of fractures may involve the entire head, yet more frequently they involve only one-half of the bone, the outer half being injured most frequently. Such a fracture usually occurs when the patient jumps from some high place and lands upon his feet, throwing a strain upon the outer side of the knee and depressing the outer half of the bone downward. More commonly this fracture is caused by a severe blow to the outer side of the knee with the knee being driven inward, such as occurs when one is struck by the fender or bumper of an automobile.

It has been the experience of the operator in this type of fracture, that the upper end of the bone has been found to be of a very soft or spongy type and can be readily compressed. When one-half of the head is compressed, the joint space between the head and femur is uneven and the joint surface is wider, thus making an abnormal weight bearing surface.

Frequently this type of fracture is overlooked because there is no definite fracture line and the only thing noted in the *x*-ray is some increase in the density of the bone running obliquely from the spine of the tibia down to the outer margin of the bone.

The important thing in the treatment of this type of fracture is the replacement of the weight bearing surface to as near normal as possible and the narrowing of the joint space. In this type of fracture there usually occurs a rather marked hematoma or effusion into the joint. This should be given the first consideration, and it is our policy when the patient is first seen to apply a Thomas splint, then to apply heat or cold as the case indicates and to keep the joint at absolute rest until the effusion subsides. If it does not subside within a period of three or four days, it is necessary occasionally to aspirate. It is rather advantageous to see that the joint swelling is reduced to a minimum before resorting to any operative procedure. Most of the cases presented in this paper were operated upon from four to five days after the injury.

## OPERATION

The operation as recommended consists first of the usual twenty-four hour preparation as for any of the bone cases. We prefer the use of an antiseptic such as metaphen, as we believe a little better preparation is carried out. The patient is then suspended upon the fracture table (Fig. 1), which permits accessability to the knee for operating and also for taking of the necessary *x*-rays at the time of the operation. A small incision is made (Fig. 2) on the outer side of the knee just below the joint and over the depressed fragment of the tibia, the fragment being fairly well exposed. A long drill which has two holes perforated in the distal end is then inserted into the fragment and the latter is elevated as much as possible, or to a point which the operator believes it should be. The drill is then passed on through the inner fragment, in a direction that when compression is applied it will be made so that the fragment is elevated and laterally approximated. When the drill has passed through the inner margin of the tibia, a second small opening is made in the skin just large enough to permit insertion of a metal button. Wire, size .039, is threaded through the holes in the drill. On this wire is threaded a button, the two loose ends of the wire are inserted into the drill holes and the wire is pulled back through the tibia. The excess wire is then removed and the second button is threaded onto the wire.

To the wire is attached an instrument that will permit tightening and the making of pressure against both buttons in order to firmly approximate the displaced fragments and hold them in position.

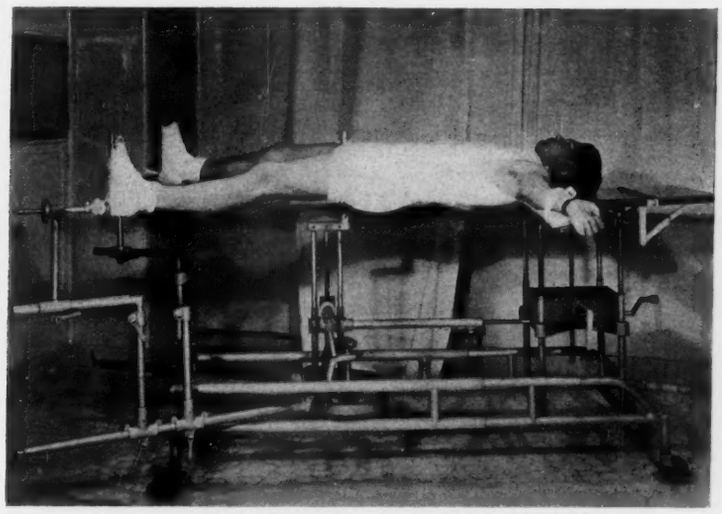

FIG. 1. Patient suspended on the fracture table.

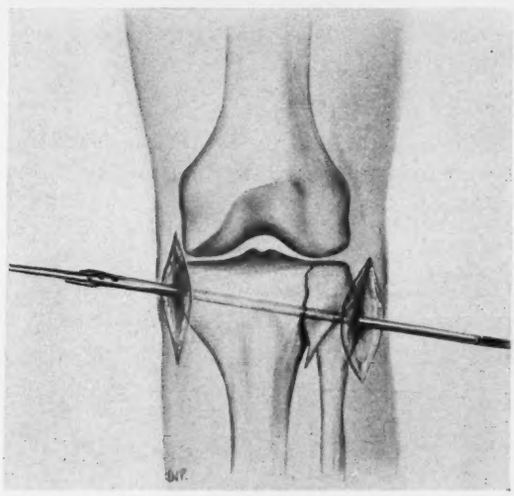

FIG. 2. Passing of drill through upper end of the tibia in the direction which would best replace the depressed fracture.

With the wire tightened as much as one thinks necessary (Fig. 3), the instrument is bent downward to permit application of a redresser (Fig. 4) in order that more lateral approximation may be obtained. With the redresser in place the wire is again tightened to take up the slack. The redresser is then removed and the leg wrapped in sterile linen and an *x*-ray is taken, first to determine that the wire

has been put through in the proper direction, and second, that the fragment has been restored to as near its normal position as possible.

After a review of the *x*-ray shows that both mentioned conditions

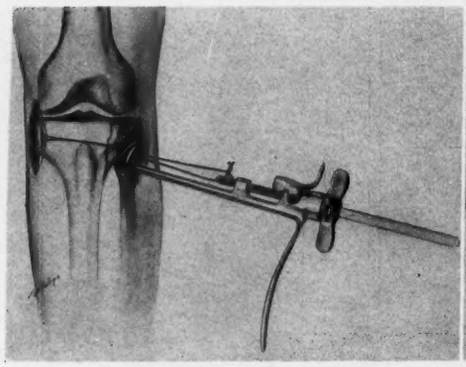

FIG. 3. Tightening of the wire by means of a special instrument which will also permit twisting and fixing buttons in place.

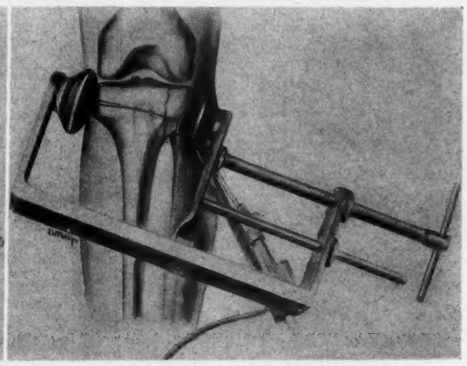

FIG. 4. Wire in place with redresser applied to make more adequate reduction.

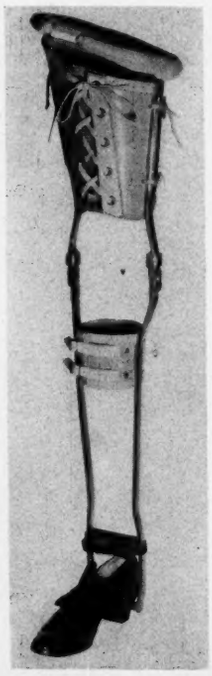

FIG. 5. Thomas ring ambulatory ischial bearing splint.

are satisfactory, the wire is twisted. This is accomplished by fixing the set-screw on the handle, then releasing the support holding the

FIG. 6. Case I. H. S. Automobile accident. Fracture of the outer half of the head of the tibia.

FIG. 7. Case II. V. M. Automobile accident. Depressed fracture of the mesial two-thirds of the tibia.

FIG. 8. Case III. C. C. Result of jumping off a high porch. Longitudinal fracture of the upper third of the tibia with lateral displacement.

FIG. 9. Case IV. M. K. Automobile accident. Fracture of the outer half of the head of the tibia.

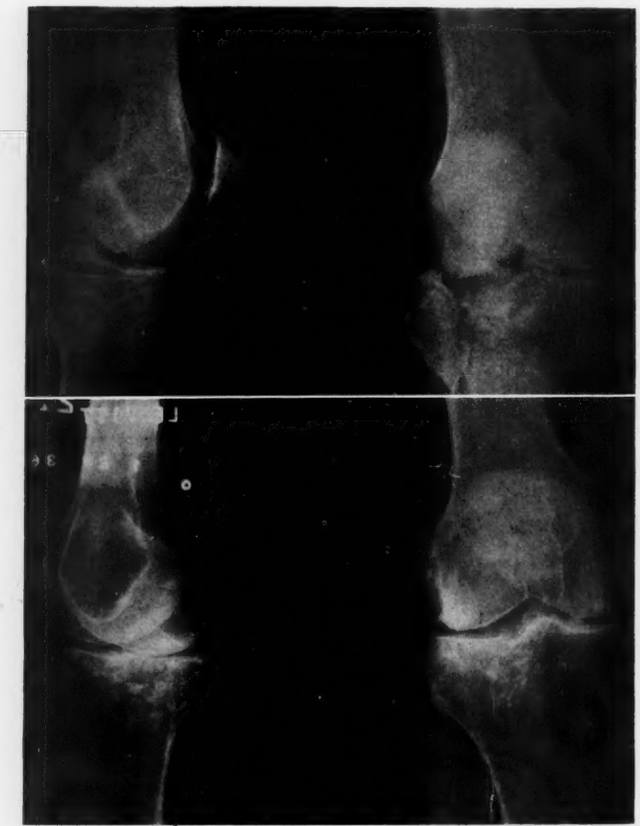

FIG. 10. Case v. H. V. Result of being struck by a log on the outer side of the knee. Fracture of the outer half of the head of the tibia.

FIG. 11. Case VI. E. E. Struck by an automobile. Fracture of the outer half of the head of the tibia.

FIG. 12. Case VII. G. S. Result of falling down stairs. Fracture of the outer half of the head of the tibia.

rod, as shown in Figure 3, to permit twisting of the wire. With this instrument the wire can be tightened with the threads remaining parallel and not twisted between the buttons, the entire twisting

FIG. 13. Case VIII. H. E. K. Struck by an automobile. Fracture of the inner half of the head of the tibia.

FIG. 14. Case IX. T. F. Struck by an automobile. Fracture of the outer half of the head of the tibia.

FIG. 15. Case X. E. E. Struck by an automobile. Fracture of the outer half of the head of the tibia.

FIG. 16. Case XI. E. K. Result of being struck by an automobile. Fracture of the outer half of the head of the tibia with marked depression of the external condyle of the humerus.

being made on the outside of the buttons. The excess is then removed and folded into the soft tissue.

The wounds are closed in due form and a plaster-molded splint is applied, using felt only as a pad. The anterior and posterior portion of the knee are left exposed to allow for any swelling that may take place.

## AFTER CARE

The after care in these cases is usually simple. The patient is given sedatives as necessary and the cast is left on for a period of

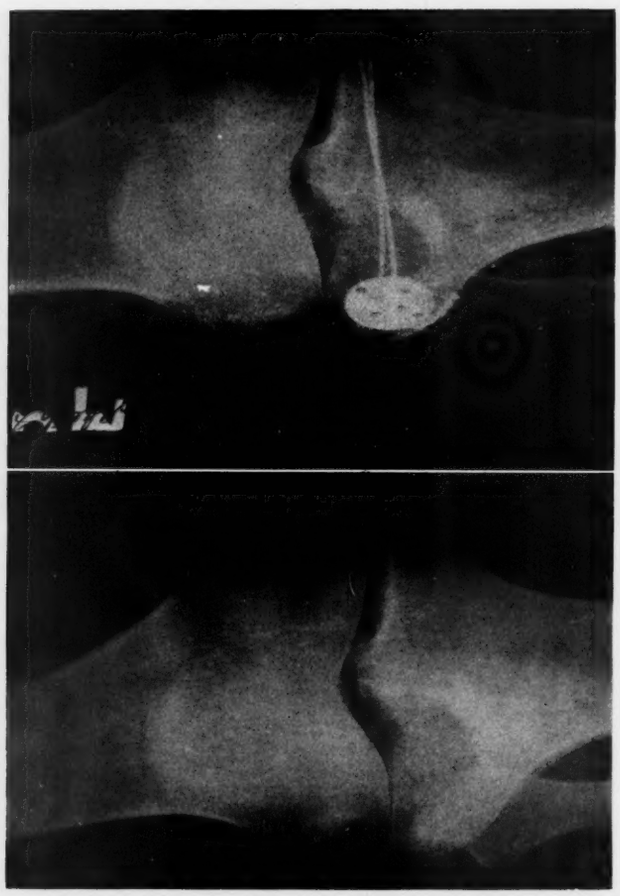

FIG. 17. Case XII. H. F. Struck by an automobile. Fracture of the outer half of the head of the tibia.

FIG. 18. Case XIII. B. J. Automobile accident. Inverted T fracture into the joint with lateral displacement.

FIG. 19. Case XIV. A. C. Struck by an automobile. Fracture of the outer half of the head of the tibia.

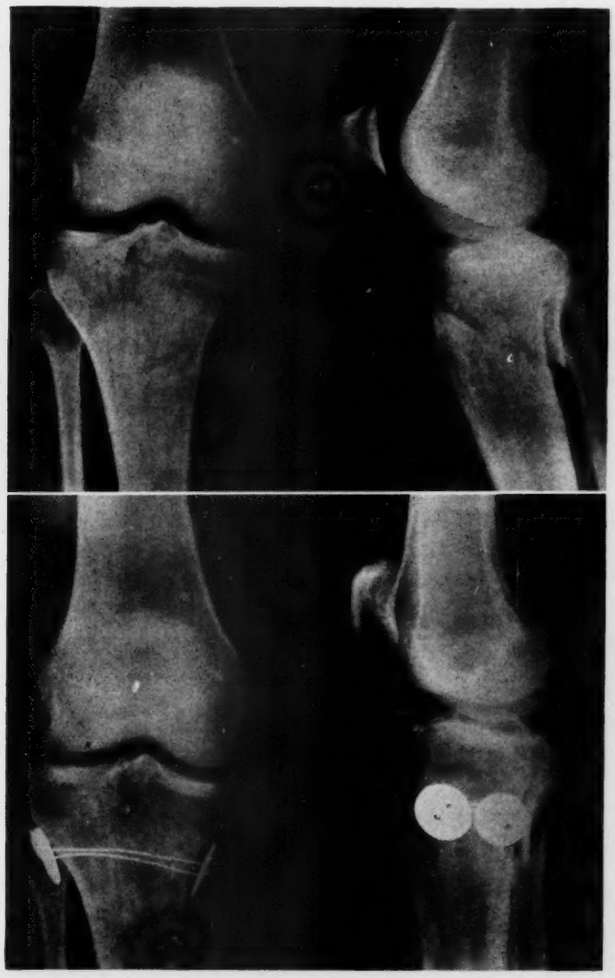

FIG. 20. Case XV. S. J. Result of falling off a trestle. Fracture of the outer half of the head of the tibia.

FIG. 21. Case XVI. P. N. Result of being struck by a log on the outer side of the knee. Fracture of the outer half of the head of the tibia.

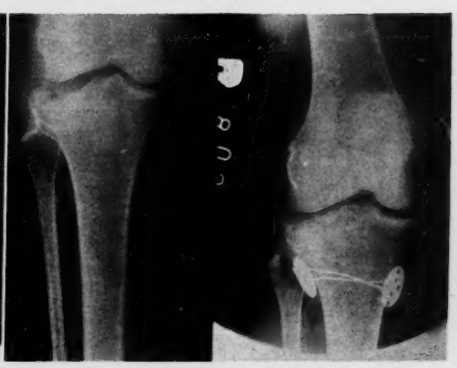

FIG. 22. Case XVII. C. L. Struck by an automobile. Fracture of the outer half of the tibia.

eighteen to twenty-one days. We have not found it necessary to remove the sutures until that period of time, but should the patient run some undue temperature the wound is inspected before that date.

FIG. 23. Case XVIII. J. D. Automobile accident. Old fracture of the outer half of the head of the tibia.

FIG. 24. Case XIX. C. S. Struck by an automobile. Fracture of the outer half of the tibia with fracture of the fibula.

FIG. 25. Case XX. T. D. McN. Automobile accident. Comminuted fracture of the outer half of the tibia.

FIG. 26. Case XXI. C. B. Struck by a jitney. Fracture of the outer half of the tibia.

When there is no occasion, we do not remove the stitches until eighteen to twenty-one days, when the plaster splints are removed and the patient is then fitted with a Thomas ring ambulatory ischial bearing splint (Fig. 5), with locks at the knee joint and a strap surrounding the knee pulling it to the outer side. With this type of splint the patient can walk and carry practically the whole weight upon the ischium and permit some weight bearing on the inner side of the joint, and with it flexion of the knee joint is permitted immediately. The wearing of this splint is necessary until such time as the fracture is firmly united. It is our practice to remove the splint daily for physiotherapy to prevent muscle atrophy and to recover

function of the joint. It is seldom necessary to remove the buttons, but occasionally some of the patients experience slight irritation, particularly on the outer side of the knee and in three of the cases presented, the buttons have been removed. Ordinarily, however, there are very few complaints and the buttons are left in permanently. We have never experienced a refracture because of the remaining wire.

The most frequent complication is arthritis. This is usually caused by the direct trauma to the joint itself. Frequently people have considerable arthritic change in the joint at the time of the accident. It is our practice to treat the patient immediately for the arthritis, and it is our policy also to clear up all foci of infection; and if the patient is found to have some definite focus, we usually give him vaccines or some of the salicylate preparations. We have found that the period of time loss has been cut down a great deal by the early treatment or the prevention of this condition.

## CONCLUSIONS

It has been our experience that:

1. An adequate diagnosis should be made, particularly to determine the degree of deformity caused by the fracture.
2. As near an anatomical reduction as possible should be made in order to prevent an abnormal weight bearing surface.
3. Early reduction is rather essential.
4. Early motion both active and passive, is very important to recover function of the joint, mainly to prevent adhesions forming in the joint.
5. An active arthritis should be prevented as much as possible.

## DISCUSSION

HUBLEY R. OWEN (Philadelphia) showed lantern slides of nine cases of fracture of the upper end of the tibia involving the knee joint. All of these fractures were "bumper fractures." Dr. Owen stated that he had never employed Dr. Buchner's technic for treating fractures of the upper end of the tibia involving the knee joint.

In the nine cases discussed, all were treated with skeletal traction and the Braun-Baylor splint followed by a fixation with plaster of Paris encasement.

In cases of malalignment of the articulus surface of the fracture head of the tibia, Dr. Owen stated that he usually had employed fixation of the fragment with nail or screw, but thought that the method of Dr. Buckner was far more feasible than the use of nail or screw.

Dr. Owen emphasized that he thought it was of great importance not to allow weight-bearing for at least ten to twelve weeks following such a fracture of the head of the tibia involving the knee joint, that is, an interarticular fracture. It is his practice to employ a brace in all fractures of the head of the tibia involving the knee joint, and in all cases of fracture of both bones of the lower leg. The type of brace includes a long cuff between the knee and the hip and another cuff around the lower leg. If weight-bearing without such brace is allowed in the interarticular fractures of the head of the tibia, the fragment is likely to become displaced and cause a permanent deformity of the knee joint, exactly similar to the danger of allowing weight-bearing with bi-malleolar fracture of the ankle joint too early.

In closing, Dr. Owen emphasized that he thought the method of Dr. Buckner was a great addition in the treatment of fractures of the head of the tibia. He thought that it also might be applicable in T-fractures of the condylar of the femur in being able to secure more accurate approximation of the fragments.

KELLOGG SPEED (Chicago, Ill.): I merely rise to ask a question. Seeing that these injuries occur not only in the Far West but also to the police of Philadelphia, who make their slips in spite of General Smedley Butler, I wonder if they ever have complications involving the semilunar cartilage, and I should like to ask Dr. Buckner when and how often it occurs in his series of cases, how he makes a diagnosis, and whether his treatment is affected by finding that the cartilage has been disrupted or torn?

CHARLES S. VENABLE (San Antonio, Tex.): I have been very much interested in this very ingenious method that Dr. Buckner has in pulling these fragments together. I think that it is a question of mechanics, and our carpenter friends taught us a long time ago the difference between a steel screw and a wood screw. A wood screw is made with a smooth shank joining the edges to the head and it will pull two pieces of wood, or bone, or what-have-you, together.

If you just use a screw that has threads all the way to the head, it will be sure to push those two fragments apart. I have one slide of this type I would like to show, to illustrate just what I mean.

This is one of these fractures we are talking about and I concur very particularly that these cases should be put in very early motion and function and with no weight-bearing. I prefer the suspension balance rather than plaster.

The base of this screw is the wood-screw tip, and the tighter you screw it, the closer it will pull the fragments together; and I think you can pull fragments together tighter with a screw than by wires or a bolt on one end of something you are pushing. I think a nail is mechanically bad because it simply stabilizes but does not give you traction across the fragments.

I wish to show that with a wood screw these fragments can be pulled up. It takes a little nick of an incision, the joint having been aspirated, a half-inch long; it is easy to do and it pulls together very tightly.

Roscoe C. Webb (Minneapolis, Minn.): I should like to express my approval of the aggressive method of treatment which Dr. Buckner has presented and to congratulate him on his results. Fractures of the upper end of the tibia are very serious and can become very disabling. When the injured man is required to do active duty, such as is required of men in railroad service, it is harder to get them back to work than is the case with men in less strenuous occupations.

During the past ten years I have used a method similar to Dr. Buckner's except that I have used a bolt which was inserted through a small lateral incision and passed through the fragments of the upper end of the tibia and tightened with a nut and washer on each end of the bolt. The following cases illustrate the types in which I have used this bolt:

The first case is that of a man thirty-five years of age who had a fracture of the external condyle of the tibia with slight displacement. He was a crane operator who had been knocked off a car, and he required seven months for return to work after the bolting operation which restored the fragments to a perfect position. His knee functioned perfectly, but he was definitely slow in getting back to work. In this case a more conservative method might have worked with equal satisfaction, but I present this case chiefly to illustrate that even in the fractures of slight degree the method does no harm.

The second case is one which is a little more severe in which the tibia is split longitudinally and the fragments are separated about one-half inch apart. This man was a brakeman operated upon in 1930, and at that time I used an ordinary long $\frac{3}{16}$ inch bolt which costs a nickle at the hardware store. The bolt is tightened in the operating room under *x*-ray guidance and the fragments are perfectly restored. The patient was placed in suspension in a Thomas splint with a Pearson attachment and early motion was instituted. He also had a fracture of the shaft of the tibia which required traction, and balanced traction was applied enabling him to move his knee joint while traction was maintained according to the method which I have described in Christopher's "Textbook of Surgery." In this case, which was of the moderately severe type, the application of the bolt was distinctly helpful and useful.

The third case is of the most severe type. The man fell from the side of a locomotive and struck his knee on a rail causing very extensive comminution and displacement of the upper end of the tibia. The bone was fractured into numerous pieces, but there is a fairly good portion of the condyle on each side of the joint which is available for bolting. He was placed in suspension and balanced traction, and an effort was made to restore the fragments without bolting until some of the swelling and ecchymosis had

subsided. The bolt was then applied through two small incisions on each side of the upper end of the tibia and suspension and balanced traction were instituted with exercise of the joint as soon as he came out of the anesthetic. The slides show that he is able to extend his knee normally and flex his knee almost normally. This man returned to work as a locomotive fireman ten months and one day after injury with a perfectly functioning knee. During the winter, a year and a half after injury, he did considerable skating and at one time skated for four hours continuously. This case represents the most severe type which in my opinion can not be successfully handled in any other method than that of bolting or wiring as described by Dr. Buckner. A through-and-through method of firmly holding the fragments on either side is absolutely necessary. The use of a screw or a nail would not be satisfactory because early motion is necessary, and early motion would loosen the screws and nails.

The three cases which I have shown demonstrate that in the less severe type the bolt did no harm; in the moderately severe type the bolt was distinctly helpful, and in the most severe type it offered the only method which in my experience has produced satisfactory results. I have not found it necessary to open the knee joint in any of my cases. If there was a loose fragment in the joint or an injured meniscus, a later operation could easily remove them. The early motion of the knee joint tends to restore the upper end of the tibia and make it possible for the joint to function satisfactorily. I have used ordinary hardware store bolts with washers on each end and tightened with a nut. An ordinary bolt cutter is used to cut off the end of the bolt flush with the nut after it has been properly tightened under *x*-ray guidance. I have removed the bolt only in one case, and there was no special indication for the removal of that bolt other than the patient's apprehension and my curiosity. In recent years I have used an ordinary $\frac{3}{32}$ inch bolt which is strong enough for this purpose. Some of the instrument makers are now furnishing this size bolt made with nuts and washers of stainless steel.

I should like again to second Dr. Buckner's method and to insist with him that patients with fractures of the upper end of the tibia receive more aggressive treatment.

CLAY RAY MURRAY (New York City): I agree very thoroughly with the principles expressed by Dr. Buckner in his procedure for fractures of the upper end of the tibia. The ideal case is always the one in which there is a single large fragment. The cases that require operation are those in which there is disturbance of the articular surface, both from the standpoint of pain due to strain on the joint, because of malposition of the upper end of the tibia, and also because of later arthritic changes in the joint, due to the rough, irregular surface.

In many of the cases of this type on which we have operated we have found lesions of the cartilage on the affected side. We have always operated through an incision which thoroughly exposed the knee joint. Where the

cartilage has been torn loose or damaged, it has been removed at the time of operation.

One other point which has impressed us has been that when you do view the knee joint in many of the cases, particularly where comminution has occurred, although a main fragment may be pulled up into position, there are multiple small fragments which lie between the main fragment and the shaft, and give to the articular surface an extreme degree, at times, of irregularity. By reasoning of opening the joint, it has been possible to rearrange the articular surface in the gap between the main fragment and the shaft so that a relatively smooth, even surface was left. We have thought that this was a distinct advantage.

I also thoroughly agree with what Dr. Venable and Dr. Webb have said, that these cases should not be immobilized postoperatively. One advantage of fixing the fragment is that early mobilization after operation can be practiced with safety in balanced suspension, with preservation of motion, not so much from the standpoint of the ultimate result but from the economic standpoint of the time taken to secure that result and to get return to duty.

Also I agree that late weight-bearing is desirable rather than early weight-bearing. It is true, again, as with so many other things, that you can "get away" with early weight-bearing in many of these cases, but the cases that do collapse, since this is cancellous bone in which the callus remains relatively soft for a long period of time, present later distortions of the surface which are almost as bad sometimes as the original injury.

H. T. Buckner (closing): In regard to exposing the knee joint, I have not believed that it is necessary to do so, and in the after reports of the patients, in the forty-six that I have operated on, there has been no locking of the knee nor evidences of injury to the cartilages; and because of that I am of the opinion that it was a simpler procedure to make the small incision and put on the fixation. I do not think it matters much whether you use the bolt or the wire, but some method is very desirable in these types of cases.

In regard to the early weight-bearing, weight-bearing should not be permitted without a support, and the ring splint, I believe, is one. Many surgeons use the splint without the ring, but with weight-bearing with the aid of the ring, they get little weight on the joint itself; consequently, it permits function of the leg and early restoration.

# SOME OBSERVATIONS ON FRACTURES OF LONG BONES IN CHILDREN*

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DURING the last ten years 2,094 fractures of the long bones have been treated on the Children's Surgical Service at Bellevue Hospital. All of the children with these fractures were under thirteen years of age and all were admitted to the wards of the Hospital. Fifteen hundred and fifty of these fractures, or 75 per cent, were of the long bones of the upper extremity. The radius was the bone most commonly fractured, being injured in 933 cases, an instance of 45 per cent. The next bone in frequency was the humerus, with 404 fractures, an instance of 19 per cent. The tibia came third in frequency, with 323 fractures, an instance of 15.5 per cent. The femur was fourth, with 189 fractures, an instance of nearly 10 per cent. Fracture of the clavicle, which is said to be so common during childhood, was in fifth place, with only 153 cases, an instance of but 7.6 per cent.

We believe that the treatment of fractures in children requires a special training. A knowledge of the structure of the bones during the successive pre-adolescent years is of the utmost importance for one who is to treat fractures during childhood. Without this preparation the surgeon is unable correctly to interpret *x*-ray findings or to select the most advantageous method of treatment. Besides this special anatomical knowledge, he should also know the manner of growth of the bones of the skeleton, otherwise a useless operative risk may be taken or an erroneous prognostic forecast may be made. Nature, through growth of the bone, does much to eliminate deformities that are the result of faulty position of fragments. Examples of this will be shown by us. Finally, the young surgeon should have had some practical training under the supervision of one who is experienced in this type of surgery, as judgment is as requisite in this form of practice as it is in any other special field of medicine.

The shape of a long bone of an infant differs but little from that of an adult; though its extremities are proportionately thicker, its conformation is much the same as that of the matured bone. How-

* From the Children's Surgical Service, Bellevue Hospital.

ever, because of our familiarity with the depicted outline of an infant's bone, as observed in roentgenograms, we naturally may picture the bone in our minds as a shaft with small, rounded extremities which are separated from the neighboring bones by wide joint spaces. This aberration, however, is apparent only in the roentgenogram, because the *x*-ray easily penetrates the cartilaginous epiphyses, leaving only an impression of the osseous tissue upon the sensitized film. Some years later the centers of ossification appear in the epiphyses and these cast their shadows from the *x*-ray as rounded masses. Still later, the epiphyses become fully ossified and their outlines are completely shown, except for the epiphyseal line which represents the position of the conjugal cartilage.

Fractures through the cartilaginous epiphyses of the long bones are not altogether uncommon. The epiphyses of the distal extremity of the humerus are those most frequently injured; but, because of the failure of the *x*-ray to visualize the loss of continuity in cartilage, a fracture of the epiphysis in a young child can be detected only by means of the physical signs that may be present. In the case of older children, in whom the centers of ossification have appeared, though a fracture line is not discernible in the roentgenogram, the displacement of the fragment can often be ascertained by noting disturbances in the relationship of the centers to one another or to the metaphysis. This condition is most often found in fractures about the elbow joint. It seems evident that if this method of diagnosis is to be used the surgeon must not only be skilled in interpreting physical signs, but should also be acquainted with the development of the bony centers of the epiphyses and to the relative position of their shadows to that of the diaphysis and to one another as observed in roentgenograms. The following case is given as an illustration:

A boy, two years of age, was admitted to the Children's Surgical Service, Bellevue Hospital, having injured his left elbow two days previously. On physical examination the soft tissues covering the lateral surface of the elbow joint were found to be ecchymotic and swollen; lateral motion was present and a mobile fragment could be felt beneath the skin. *X*-ray examination showed this fragment to consist of an elliptical mass, about 1 cm. in length and ¾ cm. in breadth, which lay laterally and dorsally to the metaphysis. (Fig. 1.) A diagnosis of fracture of the lateral condyle was made. Attempts to obtain reduction failed and the child was operated upon. On exposing the fragment it was found to be an irregular mass of cartilage and bone which was easily recognized to be the lateral condyle, composed of a fragment of bone from the diaphysis, representing the

epicondyle and juxta-epiphyseal region of the lateral half of the metaphysis, and the lateral half of the epiphysis, laid down in cartilage (for the center of ossification for the capitellum had not as yet appeared). This fragment,

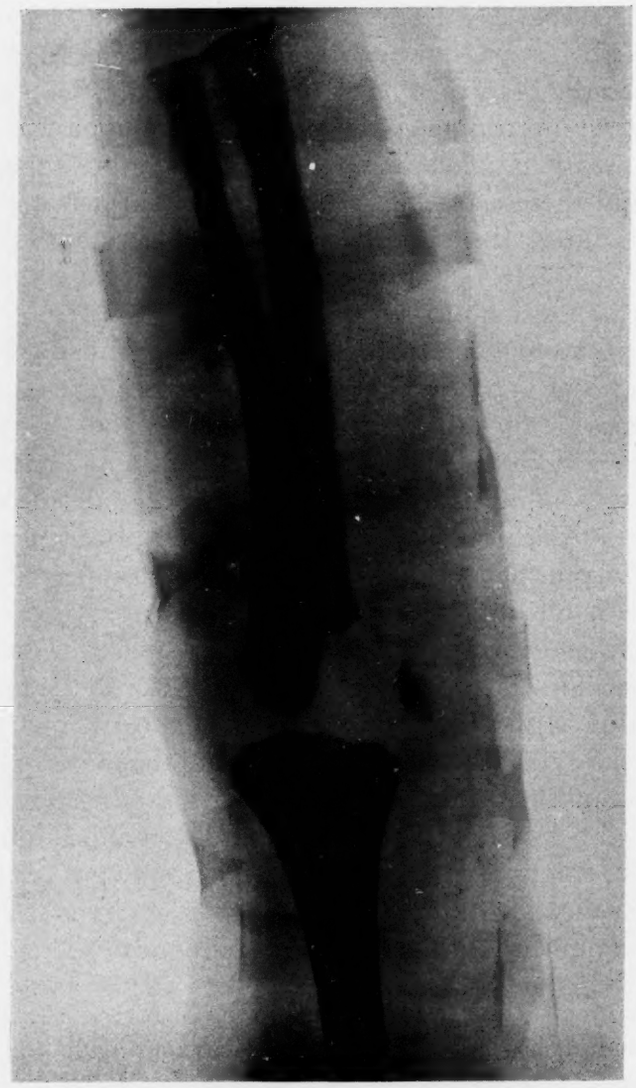


FIG. 1. Fracture of the lateral condyle in a child two years of age.

to which the extensor muscles of the forearm were attached, had been rotated so that it could not be replaced until its axis was straightened.

Longitudinal growth of a long bone occurs through the proliferation of the cells in the epiphyseal cartilage plate. Haas has shown that the proliferating cells which produce growth are those that border upon the epiphysis and, consequently, that damage to the epiphyseal

surface of the cartilage plate produces cessation of growth; while injury to the juxta-epiphyseal region of the metaphysis does not necessarily effect growth. These findings are substantiated by clinical experience.

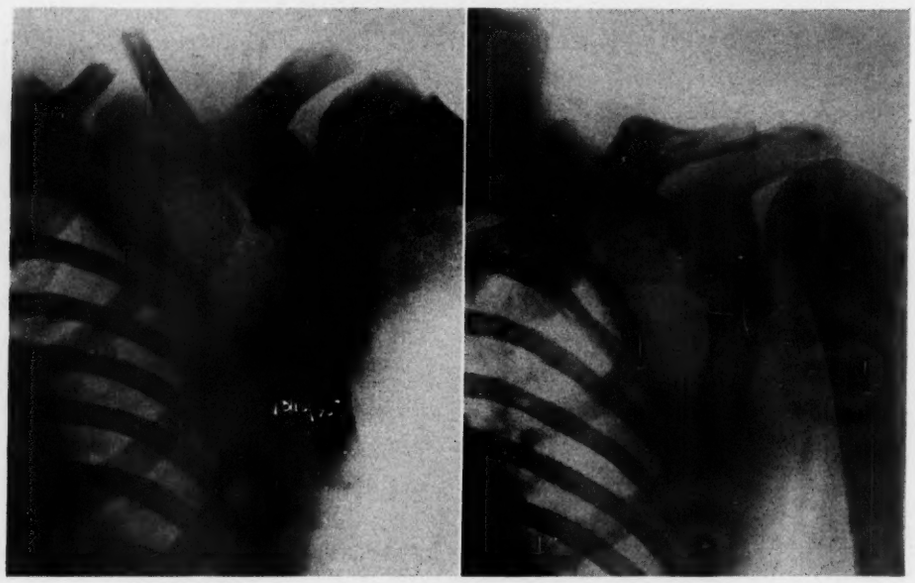
The periosteum of the child is not as firmly attached to the cortex of the bone as that of the adult. Consequently, it is often stripped from the surfaces of the fragments in fractures, forming a tube-like bridge between the fragments. This, as will be shown, guides the formation of callus across gaps between the fractured surfaces, thereby re-establishing the continuity of the bone. Meanwhile, the misplaced ends of the fragments become absorbed. Thus a malalignment often becomes obliterated. Aitken has demonstrated this remarkable remodeling of bones in children following fractures, in reports on the end results of fractures of the distal radial epiphysis, the distal tibial epiphysis and the proximal humeral epiphysis. Some examples have also been published by us.

A separation or dislocation of an epiphysis should be considered as a fracture through the metaphysis. Often the fracture line is irregular and a small fragment of bone from the metaphysis may be found to be separated with the displaced epiphysis. Microscopic investigation in these cases shows us that the line of separation passes through the soft new bone of the juxta-epiphyseal region. Many of the malalignments resulting from epiphyseal displacement, as in fractures through the metaphysis, if not reduced become corrected by the processes of Nature within a few months through the deposition of new bone on the one surface of the shaft as, simultaneously, the bone on the opposing surface is absorbed. Such deformity or shortening that may occur in this type of injury is due in almost all cases to damage of the actively growing cartilage plate. Aitken has said, "Malposition of the epiphysis per se, is not a cause of deformity." This statement has been borne out by our experience.

A fracture through the juxta-epiphyseal region, causing a separation of the epiphysis, does not necessarily damage the cartilage plate. If, however, the line of fracture passes across the plate, the damage to the cartilage cells bordering upon the epiphysis usually results in a cessation of growth, causing a shortening of the bone or a varus or valgus deformity. A fracture of the bony epiphysis itself may also damage the proliferating cells of the cartilage.

Incomplete fractures are much more common among children than older individuals. They are of two varieties: subperiosteal fractures through the metaphysis (as exemplified by certain fractures of

the radius or tibia), with no displacement, and the so-called "green-stick" fracture of the shaft, in which there is a bowing of the bone. To restore the axis of the bone in the latter type, the fracture should



A B

FIG. 2 . A, compound fracture of the outer third of the clavicle; fracture of body and neck of the scapula. B, end result. (From Beekman, Fenwick. Fracture Dislocation of the Clavicle. *Am. Surg.*, vol. 105, No. 3, 1937.)

be completed, otherwise refracture or deformity almost always recurs. Delayed or nonunion in simple fractures during the period of childhood are extremely rare occurrences. During the last ten years we have not seen a single instance of nonunion in any simple fracture in this series of over 2,000 cases.

Fractures of the clavicle in children occur in the middle third of the bone; most of them are the so-called "green-stick" variety. Even though reduction is obtained, deformity invariably recurs, as it seems to be impossible to obtain satisfactory immobilization. Nevertheless, the end results we find are excellent. The malalignment is eventually corrected, excess callus is absorbed, and full length is re-established during growth. The following remarkable case is reported:

A boy, eleven years of age, was crushed between a truck and a wall. He was admitted to Bellevue Hospital suffering from shock. There was a wound in the left supraclavicular fossa from which there was copious bleeding. A roentgenogram showed a fracture through the mid third of the clavicle and a dislocation of its acromion end. The fragment lay in a vertical position. There was also a fracture of the body of the scapula which ran across its

neck. (Fig. 2A.) The hemorrhage was controlled by means of pressure and the arm was bandaged to the side. Forty-eight hours later the arm was abducted to a right angle by means of light traction. At the end of four weeks the formation of callus was observed bridging the gap between the end of the proximal fragment and the acromion process of the scapula. On discharge, a week later, full function had returned and there was only 1.5 cm. of shortening. Three years after the accident, the alignment was perfect; the bone, though a little thickened, was not shortened and the displaced fragment has been almost all absorbed. (Fig. 2B.)

The most common injury about the shoulder joint in children, with the exception of fracture of the clavicle, is fracture of the upper end of the humerus. In this series there were forty-four such cases, 11 per cent of all the fractures of this bone. The separation of the proximal epiphysis is most often encountered in children over twelve years of age. There was no such injury observed in our cases. The common fracture in younger children is a transverse one at a lower level than that usually observed in the adult, though fractures of the surgical neck are occasionally seen. In some of these cases there is little or no displacement. It is our opinion that unless there is actual overriding, attempts to obtain reduction are unnecessary, as only too often such attempts may end in failure. The final anatomical and functional results in all these cases of fracture of the proximal end of the humerus in this series were perfect within a few months' time, even though malposition had not always been corrected.

A boy, ten years of age, was admitted on June 25, 1933, with a transverse fracture of the left humerus. (Fig. 3A.) The line of fracture was about 1¼ inches below the epiphyseal line, the proximal fragment overriding it for about 1 inch. Attempts to lock the fragments failed. Traction and suspension were then used, without effect upon the position of the fragments. One month later there was firm union and full function had returned. An *x*-ray showed callus bridging the gap. Four months later the normal anatomical outline had been re-established and there was no evident shortening of the bone. (Fig. 3B.)

For the treatment of these fractures of the proximal end of the humerus we have usually used traction, with the arm abducted to 90° from the chest; but now we believe this to be unnecessary in most cases and that by the use of a sling or through bandaging the arm to the chest, a satisfactory result can be obtained. Again we quote Aitken, "The author wishes to emphasize the fact that mal-

position is corrected within a month. Deformity and shortening are due to damage to the actively growing cartilage plates."

Fractures of the shaft of the humerus are not uncommon. There

A B

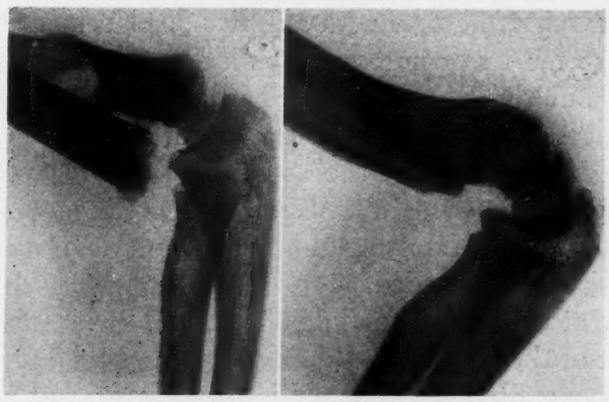
FIG. 3. Fracture of proximal extremity of the humerus, showing realignment of bone through the effects of Nature. (From Sullivan, John E. Injuries about the shoulder joint in children, exclusive of fracture of the clavicle. *Ann. Surg.*, vol. 7, No. 4, 1938.)

were fifty-eight cases in our series, 14 per cent of the fractures of the humerus. Unless accompanied by an injury of the radial nerve, which is a rare occurrence during childhood (there was none in our series), the prognosis is excellent, even though there is angulation or overriding of the fragments. Fractures of the shaft of the humerus can usually be treated in plaster splints, though in the case of some oblique fractures traction is the most satisfactory method for maintaining reduction.

The distal end of the humerus is the second most common site of fracture during the years of childhood. There were 278 cases in this series, 70 per cent of the fractures of the humerus. This is one location in which it cannot be taken for granted that Nature will eventually restore the anatomical contour and function without the assistance of the surgeon, although many malalignments are corrected through growth.

The most common type of injury is the supracondylar fracture (41 per cent of the fractures found by us in this region) in which there is a posterior displacement of the distal fragment, accompanied by more or less lateral or medial displacement and some

rotation. Early reduction is of the utmost importance in preventing ischemic contracture and nerve injury; if delayed, reduction becomes more difficult and the danger of Volkmann's ischemia is increased.



A B

FIG. 4. A, supracondylar fracture of the lower end of the humerus. B, end result. (From Beekman, Fenwick. Fractures during childhood. *Surg. Clin. North America*, April, 1934.)

In the reduction of a supracondylar fracture, particular attention must be paid to the correction of any lateral or medial shift, or rotation of the distal fragment, as these displacements inevitably result in changes of the carrying angle. We believe it is not as important to reduce the posterior displacement as Nature corrects this malalignment, and we are satisfied if we obtain a contact of at least one third of the fracture surfaces, if lateral displacement or rotation can be overcome. Though in the past these fractures were treated with the forearm maintained in a position of acute flexion, we now use the method of traction described by Dunlop. This gives excellent results, if primary manipulative reduction is used, without the danger of embarrassing circulation.

On May 9, 1927 a boy, ten years of age, was admitted to Bellevue Hospital. He had sustained a supracondylar fracture of the left humerus three weeks previously. Flexion of the elbow was limited to 90°. A roentgenogram showed the distal fragment displaced posteriorly with overriding of the proximal fragment. A bridge of new bone spanned the gap between the fragment and the dorsal surface of the cortex of the shaft; the distal end of the shaft projected into the cubital fossa, obstructing flexion of the elbow-joint. (Fig. 4A.) A year later there was little improvement. Two years after the accident the patient returned with no limitation to flexion and but slight decrease in the carrying angle. The roentgenogram obtained

at this time showed the end of the bone remolded, the projecting end of the proximal fragment having been absorbed and the shaft prolonged to the fragment by callus. (Fig. 4B.)

Supracondylar fractures with anterior displacement of the distal fragment are far less common in children. This type of fracture (there were but three cases recorded in this series, only 2 per cent of the supracondylar fractures) is due to direct violence.

Intercondylar fractures, the so-called T and Y types, are rare in children. The epiphyseal cartilage plates are invariably damaged in this type of injury, resulting in late deformity. Consequently, the prognosis should be guarded.

Fracture of the lateral condyle of the humerus is not uncommon (17 per cent of the fractures of the distal end of the humerus in this series). Occasionally the fragment is rotated, so that it cannot be replaced without an open operation (6.5 per cent of these fractures). If left unreduced, a serious deformity results which eventually may cause an ulnar nerve paralysis. Even though reduced, a gradual increase of the carrying angle may follow the injury, due to damage to the epiphyseal cartilage plate of the capitellum. Consequently, a guarded prognosis should always be given.

Fractures of the medial epicondyle are not unusual (16 per cent of the fractures of the distal end of the humerus in our series). They are usually epiphyseal separations and may result in an increase of the carrying angle without any loss of function. The condition often accompanies dislocation of the elbow, and occasionally the fragment of epicondyle may be displaced within the joint during reduction of the dislocation. In these cases, open operation is imperative.

Fracture of the neck of the radius is not uncommon (we had twenty-two cases, 2.3 per cent of the fractures of the radius). The head of the radius is seldom injured in children. Conservative treatment is advised unless a marked rotation or displacement of the head has occurred. Excision of the head of the radius in the growing individual always results in a marked increase of the carrying angle, radial deviation of the wrist, as shown by Lewis, and often in loss of rotation of the forearm. When there is considerable displacement, it is far better to attempt to replace the head in position than to excise it. But even then the results are not always good. Separation of the head at the epiphyseal line usually results in its closure. It is surprising to find the results obtained by conservative methods of treatment.

A boy, eight years of age, was admitted with a fracture of the neck of the right radius, together with a fracture of the olecranon. The head of the radius was slightly displaced laterally and there was little displacement of the olecranon. The right arm and forearm were immobilized in molded plaster splints for fifteen days and then active motion was started. In two months all motion at the elbow joint was complete, with the exception of full extension, which was limited about 10°. The carrying angle was increased about 5 per cent. After two years the carrying angle became normal but the defect in extension has persisted.

Most fractures of the forearm occur in the distal halves of the bones (82 per cent of the fractures of the shafts of bones of the forearm in this group occurred in the distal third). They are often "green-stick" in type and must be completed before a proper reduction can be obtained. Reduction is often difficult; it is merely necessary to obtain an end-to-end contact of one of the bones. Cross union seldom occurs (there was no such case in this series, except in one of a fracture of the neck of the radius). Recurrence of the bowing or refracture may occur if splints are removed too early. These fractures should therefore be splinted for at least eight weeks. A weak point of the radius is near the junction of the shaft with the metaphysis. Fractures at this site are common. The so-called "torus" fracture, a transverse break, characterized by a local expansion of the cortex, is frequently incomplete; but even when complete there is seldom much displacement. This type of fracture of the radius is often accompanied by a transverse fracture of the ulna at the same level.

The lower radial epiphysis is separated more frequently than any other (2.2 per cent of the injuries of the radius). But despite this frequency, damage to the cartilage plate is rare. Reduction of the fragment is usually accomplished with ease. However, if not reduced at first, repeated attempts or an open operation are seldom justifiable, as the alignment is invariably re-established. Even the plane of the articular surface of the radius is returned in a short time to its normal relationship with that of the axis of the shaft.

L. W., a boy of twelve, while skating fell upon his outstretched right hand. He had severe pain in the wrist. It was treated as a sprain of the wrist for five days, at which time an *x*-ray was taken which showed a posterior dislocation of the lower epiphysis of the right radius. The epiphysis was displaced by half of its diameter from the end of the diaphysis and was slightly rotated so that its articular surface was looking dorsally instead of toward the flexor surface. (Fig. 5A.) The child was seen by two surgeons

who both advised operation. Ten days following the accident the boy was referred to one of my associates, who found the fragment so firmly united to the epiphysis that it could not be moved. He advised conservatism. The

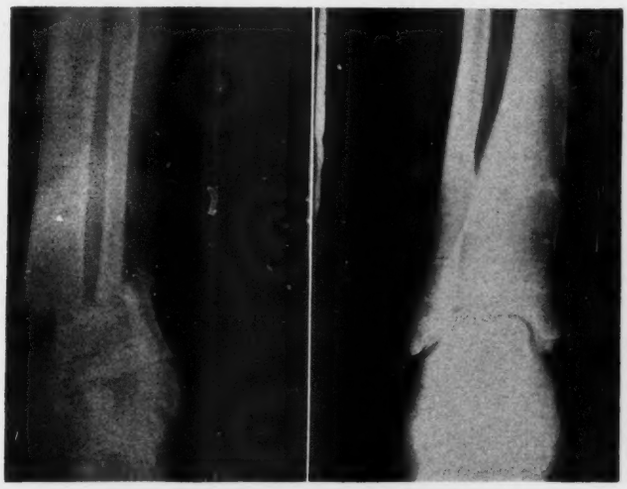
FIG. 5. A, posterior dislocation of the distal epiphysis of the radius. B, end result. (From Beekman, Fenwick. Fractures during childhood. *Surg. Clin. North America*, April, 1934.)

forearm was splinted for ten days. Fifty days later flexion was limited to 20° and all other motions were normal. Six months later the boy had normal range of motion of the wrist in all directions. (Fig. 5B.)

There have been eight cases of fracture of the neck of the femur, seven of which were treated by Russell's traction with prompt union and little or no coxa vara. The eighth case, a compound fracture, developed osteomyelitis and ankylosis of the hip joint.

There have been 150 simple fractures of the shaft of the femur. All of these have been treated by means of traction: Bryant's overhead traction to both extremities in children under four years of age, and Russell's traction in the older ones. There have been no open reductions and skeletal traction has not been used. Primary manipulation to improve position was used in many of these cases. Notwithstanding this, malposition has occurred in many. However, eventually the malalignment and shortening have been overcome through growth. It is surprising to observe how the normal alignment returns through the deposit of osseous tissue in the concavities

and the absorption of bone from the convexities of the line of union. The shortening is overcome through increased longitudinal growth at the epiphyses.



A B

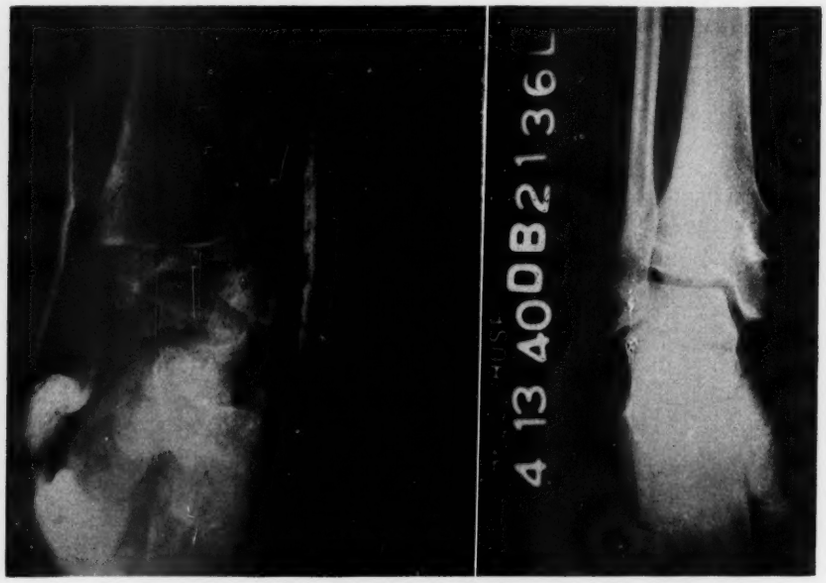
FIG. 6. A, fracture of the distal end of the tibia and fibula. B, end result.

There were twenty-three fractures of the femoral condyles, two of which were epiphyseal separations. Good results were obtained in all.

The usual fracture of the tibia in children is through the lower half of the shaft. The tibia alone may be fractured, or there may be an accompanying fracture of the fibula. (In 273 cases the tibia alone was fractured in 185. The shaft was fractured in its lower third in 197 cases, 71 per cent.) A transverse fracture of both bones, a few inches above the epiphysis, is not uncommon and, if the fragments are displaced, reduction may be difficult. Fractures of the epiphyses occasionally occur (6.5 per cent). Fractures about the ankle, so common in the adult, are seldom seen in childhood, though occasionally a fracture of the tibial epiphysis is found with displacement of the medial malleolus. The fracture line passes through the epiphysis from the joint surface toward the cartilage plate and may damage the latter, thereby causing premature closure of the epiphyseal line with a resulting varus deformity.

A good result may be expected in fractures of the tibia, provided a fair reduction is obtained and the fragments are retained in position until union is completed. Occasionally traction may be necessary. Skeletal traction is seldom needed, for in most cases the

fracture can be treated successfully after reduction with plaster. Slipping of the fragments after reduction seldom occurs. Even though malposition is not corrected, the final results are usually good.




A B

FIG. 7. A, separation of the distal epiphysis of the tibia; fracture of the lower end of the fibula. B, end result.

A girl, nine years of age, was admitted to Bellevue Hospital on September 21, 1935, with transverse fractures of both bones of the right leg, about 1 inch above their distal conjugal cartilages. The distal fragments were displaced posteriorly and laterally. (Fig. 6A.) Attempts to obtain reduction by means of manipulation failing, traction through a Kirschner wire was tried with no better success. Union occurred with the fragments in malalignment. In less than three months' time the malalignment had been overcome and the contour of the bones had been re-established. (Fig. 6B.)

The following case of badly displaced lower epiphysis of the tibia demonstrates the reformation of normal anatomical outline in such injuries, though reduction of the epiphysis has not been obtained:

A little girl, eleven years of age, was admitted with a fracture of the lower third of the tibia and fibula. An *x*-ray showed the lower epiphysis of the tibia displaced laterally, along with a portion of the metaphysis and the distal portion of the shaft of the fibula. (Fig. 7A.) An attempt was made to reduce the fracture by manual manipulation which was unsuccessful. Open reduction also failed to correct displacement. Three months later there was beginning realignment of bones and in ten months there was over 75 per cent restoration of normal contour. (Fig. 7B.) Clinically there is slight

flattening of the foot, with no deficiency of flexion or extension of the ankle and no limp.

## CONCLUSIONS

Fractures of the long bones in children differ considerably from those occurring in adults. The bones in the former are growing, so Nature is kinder in healing the fractures and can usually be depended upon to correct deformities due to malalignment. But because Nature will eventually overcome deformities, which are the results of displacements, we believe nevertheless that there is no reason why the surgeon should leave the entire responsibility to her. It must never be forgotten that there is also soft tissue damage at the time of injury and that an early reduction releases blood vessels and nerves from further injury. Consequently, by obtaining an anatomical reduction, function returns more rapidly. On the other hand, repeated attempts to obtain reduction through manipulation, traction or open operation may not only be unnecessary, but may actually cause damage. For this reason, every fracture should be treated as an individual problem after all the facts in the case have been taken into consideration. Knowing that Nature will correct most displacements, the indications for an open operation or for complicated procedures for traction are far fewer than in the case of fractures in adults.

However, the very fact that a growing bone is being dealt with may be the cause of disaster which, with our present knowledge of growth, we are unfortunately helpless to prevent; that is, in those cases of fractures which involve the cartilaginous parts of the epiphyses. These injuries may not be discovered by *x*-ray and, for this reason, the clinical signs are of the utmost importance in reaching a diagnosis. Further, though the fragments may be entirely reduced, deformities may slowly develop during growth, due to damage of the proliferating cells of the epiphyseal cartilage plate.

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## DISCUSSION

ALEXANDER P. AITKEN (Boston, Mass.): The obvious conclusion to be drawn from this paper by Dr. Beekman and Dr. Sullivan is that in the treatment of fractures of childhood we must be most conservative.

Their conclusions, of course, are based on several years' experience in a large municipal hospital where hundreds of children's fractures are seen.

At the Boston City Hospital we, too, see hundreds of fractures during the course of a year, particularly in children, and we, too, have arrived at the same conclusions.

As Dr. Beekman has said, since 1933 we have been particularly interested in epiphyseal fractures and have written a great deal on that subject. As a result of our studies, we have come to very definite conclusions. One of the slides Dr. Beekman showed you demonstrated three types of epiphyseal fractures. We believe all epiphyses are subject to these types of fracture, and that deformity is due to the type of fracture received and not to malposition. Deformity is due only to injury to the cartilage plate at the time of injury, or from operative attempts at replacement. Malposition in extra-articular epiphyses is very readily straightened out and deformity as a result does not occur. In intra-articular epiphyses, of which there are three, the external condyle, capital-femoral and proximal radial Nature does not correct malposition; consequently, displacements of these three epiphyses should be promptly operated upon. I say that although I have yet to see in fractures of the proximal radial epiphyses (which are intra-articular) a good result once it has been displaced.

I have just one slide to show. This is a case of a Type I fracture in a child that entered the City Hospital six weeks after his injury with considerable displacement. Not only is the epiphysis displaced three-quarters of the width of the shaft, but also rotated about 60 degrees. We attempted reduction but were unsuccessful. We left it alone, with our fingers crossed, and took *x*-ray plates every six weeks. This picture was taken six weeks after admission and even at that time the sharp end of the diaphysis had been rounded off and already a new shaft was being built out to the displaced epiphysis. Twelve weeks later there was still further remodeling of the end of the diaphysis. Progressive correction was seen at the end of eighteen and twenty-four weeks. At the end of one year after injury, unless you notice the absence of the normal volar curve, it would be very difficult to tell which epiphysis had been fractured.

Dr. Beekman has shown you what nature will do in long bones. We have seen marked bowing corrected in the shaft. That brings up the ques-

tion as to whether we are justified in operating upon fractures of the shaft with shortening. Will Nature make up for the shortening of a long bone?

Recently at the City Hospital we have studied seventy-one cases of fracture of the femoral shaft in children by means of four-foot films, so that we can get fairly accurate measurements of the shaft. When a shaft of a bone is broken, we get the formation of callus and there is a marked hyperemia of the periosteum as long as the callus remains. The epiphyses get all of their blood supply from the periosteum; consequently, fracture of the shaft produces a hyperemia of the periosteum and consequent hyperemia of the epiphysis. Under twelve years of age this results in an increase in the growth of the epiphysis with consequent elongation of the shaft.

This overgrowth is not compensatory, for not only will fractures with displacement show overgrowth, but also fractures that are anatomically reduced. The average overgrowth has been 1 cm. In general, the more displacement, the larger the callus, the longer the callus persists, and consequently the greater overgrowth we get.

In anatomical reductions, particularly those in which open reduction was done, we have had sufficient overgrowth of the femur to cause a tilting of the pelvis with a compensatory scoliosis. From the point of view of orthopedics, the scoliosis did not amount to much but, nevertheless, it was present. In other words, in fractures of the long bones with displacement, we can be sure that the original shortening on discharge will not persist. A great deal of it will be made up in the normal overgrowth which occurs in every fracture. If we have displacement up to half an inch, there is a question as to whether or not we are justified in doing open reduction. As long as we have malpractice, I suppose we are justified, but cases certainly in our experience, with a half inch overriding, by the end of a year will have made up that shortening. In subperiosteal or fractures without displacement, or when open reduction has been done, we can be sure that lengthening will occur.

Some will say when the child reaches full growth that the two legs will equalize. We have nine cases in which ossification of the epiphysis is complete and those patients have maintained their overgrowth.

JOHN A. CALDWELL (Cincinnati, Ohio): The particular features seen in fractures of long bones in children which have been stressed by Dr. Beekman accord completely with our experience at the Cincinnati General Hospital Fracture service.

Several years ago we reviewed our cases of fracture of the femur in children. The total number was 443 and there was no open operation in any of these. This did not mean that we had good position in all cases, but even when the relation of fragments was poor, the final result was good. None of these cases had any impairment of function or deformity.

The outstanding case occurred in 1916. In spite of all efforts short of open fixation, it united by excessive callus and 1¼ inch shortening. Exami-

nation two years later showed a slight alteration of the axis of the femur with some enlargement of the bone, and careful measurement showed the injured leg 3/8 inch longer than the other.

This patient came back twenty-two years later bringing her own child to the Fracture Clinic, when measurement of the two legs still showed 3/8 inch lengthening, but *x*-rays of both legs did not disclose any alteration of contour.

I wish to concur particularly in emphasizing the importance of replacement in epiphyseal separation. I have had two tragic results following failure to replace a displaced lower femoral epiphysis. Both were cases which I did not see until late and unclean wounds in the region of the injury prevented correction by open exposure. In one case erosion of the popliteal artery necessitated a supracondylar amputation and in the other case, thrombosis of the artery was followed by marked vascular insufficiency of the leg and foot.

KELLOGG SPEED (Chicago, Ill.): In corroboration of what has been said, I should like to show a few slides, entering a plea for delayed and possibly minor operative procedures.

FENWICK BEEKMAN (closing): There is very little for me to say in rebuttal because I think that most people who have discussed this paper agree with us in principle. I want to thank those who have discussed it today.

The fracture that causes the greatest amount of worry is the fracture of the neck of the radius. In these we have tried all types of treatment. We tried at first, many years ago, the excision of the head, and had very poor results, increased carrying angle and a change in the wrist. We then attempted in a few cases to replace the head but were not successful in getting good results. We find that unless the head has been completely rotated in its plane, it is best to leave it alone. No one, I believe, should be in a hurry to go in and remove the head of the radius in a child.

# PRIMARY OPERATIVE FIXATION IN FRACTURES OF THE LONG BONES IN ADULTS*

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THERE is probably no subject in the field of the surgery of trauma today so characterized by grave differences in opinion and practice as that of the operative fixation of fractures. Study of the literature on this subject covering the last twenty-five years, familiarity with the procedures which have been and are used at operation and during the after care of cases in many sections of the country, personal discussions with many of the men who have been either for or against the practice over the same period of time and an intensive study of the subject for the last twelve years conducted by the Fracture Service of the Presbyterian Hospital, have all made it appear distinctly worth while to present an evaluation of the situation at the present time.

The reason for a great deal of the difference in opinion as to the value of the procedure lies in what might be called language difficulties. "Open reduction" means little or nothing unless the procedure and the postreduction treatment are rigidly defined, and unless the underlying purpose of operation is clearly understood.

Particular attention is directed at the outset to the fact that this paper does not urge or advise the widespread adoption of primary operative fixation of adult long bone fractures *except under certain definite conditions*. When and where these conditions cannot be established, it advises *against* the procedure and advocates operative fixation only by virtue of necessity.

This leads to the first basic problem: What is the purpose of operative reduction? In attempting to answer this question we must immediately define two broad groups of cases. One group comprises those patients who are operated upon *by virtue of necessity;* the other group is composed of those patients subjected to primary operative

* From the Department of Surgery, College of Physicians and Surgeons, Columbia University and the Fracture Service of the Presbyterian Hospital. Read before the American Association for the Surgery of Trauma, Atlantic City, June 8, 1940.

reduction *as the method of choice*, although amenable to other and more conservative forms of treatment.

In the first group the necessity for operation may be forced by: (1) fixed interposition of tissue between the bone ends (muscle, fascia, periosteum, or loose bone fragments) recognized at the outset by clinical evidence or later on by failure of union; (2) failure to secure adequate reduction by fair trial of more conservative measures over a reasonable period of time; (3) common and accepted knowledge that satisfactory end results can be secured *only* by operation—such cases as fractures of the patella, olecranon or radial head, with wide separation of the fragments; (4) coincident soft part injuries (nerve, vascular or joint) which per se necessitate exploration; and (5) compound fractures. In this whole group of cases the operative reduction is dictated by the pathological conditions present, and reasonably satisfactory results cannot be expected by any other means. This group is not, therefore, the subject of our discussion, nevertheless much of what is said subsequently concerning the actual operative reduction and fixation of adult long bone fractures is applicable to it.

Our discussion deals with the use of primary operative reduction and internal fixation as the method of choice in adult long bone fractures in which it is generally agreed that more conservative measures will result in reasonably satisfactory end results. The discussion will be developed by answering the following questions:

1. Does the use of primary operative fixation of adult long bone fractures have theoretical advantages over closed methods of sufficient weight to warrent its consideration?

2. Can these theoretical advantages be translated into comparable practical benefits without appreciable risk to life or limb of the patient?

3. What conditions are essential if this is to be safely done?

4. How can these conditions be best established?

*Question* 1. The theoretical basis for primary operative fixation of adult long bone fractures as an optimum method.

The ideal method of treating a fracture would be to "wish" the fragments into place with concomitant abolition of all pathological reaction, to hold them rigidly fixed in place by "moral suasion," and to allow the patient to resume his normal activities immediately. This translates itself in practical terms into early reduction with a minimum of violence to bone and soft parts, supplemented by measures designed to reduce pathological reaction in the tissues, as rigid a

fixation of the bone fragments as is possible and the institution of active function in all the joints of the part as soon after injury as possible.

These principles must be carried out insofar as possible even if closed methods are used, if the methods are to be sound. But it is obvious that closed methods, no matter how well utilized, must frequently secure reduction at the expense of considerable manipulative trauma, must often rest content with only partial reductions, must depend upon the relatively slow and inefficient means of position and physical therapy (when they can be used) for the reduction of soft part pathology, and must of necessity immobilize part or all of the involved extremity.

When pins or wires inserted into the bone are included in the immobilizing plaster to minimize the amount of joint immobilization, the reduction can be accomplished with less trauma, the fixation is more nearly a rigid one, and the mobilization of the adjacent joints may be more freely carried out. This is definitely a nearer approach to our ideal than is simple closed reduction and immobilization. But anatomical reductions in these cases may still be difficult, the fixation of the bone fragments is still relative, the pathological process in the tissues is attached only through the added amount of mobilization possible in the joints of the extremity and this latter is often only partial.

Traction-suspension in its various forms, if properly and successfully carried out, provides a near approach to "wishing" the fragments into place, allows of early attack on the pathological process in the soft parts by position and physical therapy, and provides, in some of its forms, for limited mobilization of some of the joints of the extremity. It often fails, however, to secure satisfactory reduction; it gives only relative fixation of the fragments; and if position and arrangement of the apparatus are not under constant and meticulous supervision, it may fail in all of its aims.

Pin-plaster fixation and skeletal traction both add to the story an additional risk, that of infection at the sites of pin or wire insertion. Excluding those cases in which the pins or wires are improperly used and in which the sites of insertion are subsequently inadequately cared for, this infection rate should be very low in soft parts, almost nil in the bone, and should increase in proportion to the amount of mobilization of the extremity practiced. If a statistical study is made of the rate of infection in cases in which pins and wires are used either in pin-plaster fixation or in skeletal traction in general use, it will be

found to be quite high for both soft parts and bone. This high general rate is to be laid, however, to improper use of the method and to lack of subsequent supervision, as well as to the generalized idea that the use of pins and wires in fracture treatment is a perfectly simple and harmless procedure requiring only the most sketchy observance of surgical principles and technic.

Theoretically, operative fixation is the only method of treatment which can simultaneously provide a relatively atraumatic anatomical reduction with coincident abolition of a large part of the pathological process in the tissues, rigid fixation of the reduced fracture and extremely early and full mobilization of the extremity involved. A properly done operative fixation should do much less actual damage than many manipulative procedures. If done at the proper time, it should free the tissues of much of the pathological results of the injury. Anatomical reduction can be secured. If rigid fixation and adequate dispersion of the forces acting on the materials used in fixation are obtained, it should be sufficient to allow full and active mobilization of all the joints of the extremity rapidly after operation.

It is obvious that open reductions followed by plaster or other immobilization do not enter this category. Open reductions in which the internal fixation is not such as to allow mobilization postoperatively, with safety and without fear of loss of the rigidity of fixation, should not be subjected to operation as a method of choice. Adequate and safe fixation must be attainable and postoperative immobilization should be unnecessary in order to warrant the use of the method. It is also clear that if operative reduction is accompanied by any appreciable risk of infection, or if there is any greater mortality than by closed reduction in similar fractures, the method is not justified. On theoretical grounds neither of these conditions should hold true.

*Question* 2. Can these theoretical advantages be translated into comparable practical benefits without appreciable risk to life or limb of the patient?

The answer to this question is "yes." It has been demonstrated in other clinics as well as in our own. In the last twelve years on the Fracture Service of the Presbyterian Hospital the staff has treated over 13,000 fractures, and has done over 600 open reductions. I say the staff advisedly, for every single case is discussed and argued pro and con by every member of the staff, either at the time of the treatment, in the subsequent ward and outpatient course, at the Friday morning Staff Conference or at Follow-Up Clinic. Free and open

discussion is encouraged at all times, and any conclusions here presented are the consensus of a group who have critically analyzed each case as a group, and are not based on the opinion of a single individual.

As practiced in our hands, the routine use of this method in comparison with closed methods under the conditions described in adult fractures of the shafts of both bones of the leg, of the femur, and of the humerus has resulted in: (1) better anatomical results; (2) fewer long-standing or permanent disabilities; (3) shortening of convalescence, as evidenced by the date of resumption of normal activities by one-third to one-half; and (4) increased speed of fracure healing and lessened rate of delayed and nonunion as evidenced by *x*-ray findings. In fractures of both bones of the forearm we had not devised until recently an adequately rigid fixation allowing active rotation of the radius and ulna without risk; and although the results now being attained in this group seem to parallel those obtained in the other long bones, they are not as yet numerous enough nor of long enough standing to warrant our drawing definite conclusions.

It is to be kept in mind that both closed and open methods have been carried out by the same group and under as nearly optimum conditions as could be created, and that 90 per cent of the cases have been followed after the completion of all treatment for from two to ten years by the group as a whole. Critical analyses of the individual case groups and detailed discussion of technics are being prepared, and will be published.* This paper is devoted to an evaluation of the principles involved.

After careful observation and comparison over this period of twelve years we have reached the point where we operate by choice on all adults who have fractures of the femoral shaft, fractures of the

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5. DARRACH, WILLIAM. Fracture of shaft of femur—open reduction and internal fixation. *Am. J. Surg.*, 44: 177; 1940.

6. MURRAY, CLAY RAY and HUDACK, STEPHEN S. Scientific exhibit on method and results of operative fixation of adult long bones at American Academy of Orthopedic Surgeons' meeting, New Orleans, January, 1941. Gold medal award.

tibia, and fractures of the humeral shaft, even though adequate position may be secured by nonoperative means, unless there is a definite contraindication to operation. This is subject, of course, to established and essential conditions which will be detailed below. With these conditions in effect the contraindications to operation in our hands are: (1) the patient as an operative risk; (2) skin conditions entailing risk of infection; and (3) mechanical features of the fracture itself precluding or making doubtful the possibility of rigid fixation of the fragments at operation. We have not had a mortality in an operative reduction as the method of choice in an adult long bone fracture. The infection rate in the same group of cases, with the culture of any organism whatever from any type of exudate as the criterion of infection, has been nine-tenths of 1 per cent, and the rate of infection leading to any prolongation of the patients' convalescence has been three-tenths of 1 per cent since the present technic and fixation materials have been used.

*Question* 3. What conditions are essential if this is to be safely done?

If operation is to be done, it is better done as an emergency and within as few hours after fracture as possible than after a wait of many hours or days. If done early before the pathological process becomes established in the tissues, and before the muscles have ceased to be elastic and have become instead extensively infiltrated and solidified, the reduction is accomplished with less trauma, and pathological products of tissue death, hemorrhage, inflammatory exudate and transudate are allowed to escape from the tissues. This, we are convinced, has a definite effect on the healing of bone. The period in which these results can be accomplished diminishes steadily through the first eight to twelve hours, and open reduction as a primary procedure definitely loses some of its value if delayed for twelve to sixteen hours after injury. In the early operation the bleeding is less extensive and more easily controlled. We are thoroughly satisfied that the risk of infection is less in the cases done within the first few hours and that wound healing is more rapid and more satisfactory. Postoperative institution of active function in balanced suspension is more readily accomplished in the patients operated upon early since there is a minimum of residual pathology in the soft part structures.

A Lane technic is desirable if it can be developed. We use it routinely. It is not, however, essential. If the Lane technic is not used, an exceedingly meticulous technic must be cultivated. The

skin must be carefully prepared and must be carefully blocked off immediately after the incision is made. Gentle handling of the tissues is much more important than speed of operation. The fingers should be kept out of the wound, and instruments should be kept from dragging over drapes, etc., in going to and from the wound. Careful hemostasis is important. A fine silk technic is better than a catgut technic. Minimal periosteal stripping, and, more important still, minimal stripping of the soft parts from periosteum, should be practiced. The approaches should, insofar as possible, be made through intermuscular planes.

In addition to the time of operation and the use of meticulous surgical technic other requirements are: (1) accurate reduction with a minimum of trauma; (2) rigid fixation of the bone fragments allowing postoperative mobilization; (3) early active mobilization in balanced suspension, starting seventy-two or ninety-six hours postoperatively and including all joints of the extremity. This must be enforced, in increasing amount and range, for short periods at frequent intervals, "every hour on the hour like the trains to Philadelphia"; and (4) early weight bearing in lower extremity fractures with brace protection until *x*-ray evidence of union permits the elimination of the brace support. Complete bony union and full function of the extremity should then be synonymous.

1. *Accurate Reduction and a Minimum of Trauma.* There must be not only early reduction, but adequate equipment to make that reduction as mechanically easy and as nontraumatic as possible, and adequate and extensive exposure to minimize the trauma of retraction, etc.

2. *Rigid Fixation.* The fixation must be by a material which will stand the strain of active function of the part in balanced suspension so applied as to distribute the strain on the fixation material to eliminate risk of breakage, and which at the same time is sufficiently chemically inert in the tissues not to cause any clinical evidence of reaction. We use a 19 and 9 chrome-nickel stainless steel, polished with a nonferrous buffer and passivated in nitric acid to remove surface defects and impurities. Other metals can be used, provided they meet these requirements. Cast metals may be inert, but internal casting defects make them risky to use because of the threat of breaking under the strain of functional activity and fatigue strain. Some of the metals formerly used, such as vanadium steel, broke under functional strain. The fixation must be in two planes. Rigid fixation, with adequate dispersion of functional strain, cannot be

secured with a one plane fixation. The single greatest cause of absorption and irritation about plates and screws is mechanical—lack of rigid fixation and failure to apply fixation so that the bone about the material used does not have to stand undue strain. It is necessary to use a plate which is four to five times the diameter of the bone, to fasten it by screws which go through both cortices of the bone at right angles to the plate, and to take up the torsional and shearing strains at the fracture site by screws which pass, either directly or obliquely, from one fragment through the other in a plane approximately at right angles to the plane of the screws holding the plate. The screws, plates, screw drivers and drills, and the use of them must be mechanically sound. Operative fixation in principle has been too often blamed for failures due to mechanically defective apparatus or a mechanically unsound use of the apparatus.

3. *Early Active Mobilization.* This requires a properly set up apparatus, with adequate and continuous supervision of it and the patient's exercise.

4. *Early Weight Bearing.* This requires accurate brace fitting, adequate instruction of the patient in brace walking with and without crutches and supervision of his activities until he is adept.

It becomes obvious that the surgeon who desires to use operative reduction as a method of choice must acquire the necessary mechanical knowledge and mechanical skill, and cultivate a meticulous surgical technic. He must have a technically excellent operating room and operating room personnel thoroughly familiar with the method and its demands. The armamentarium in instruments and apparatus must be mechanically adequate and its use thoroughly understood. Postoperative care to insure that functional activity is resumed and consistently practiced requires properly trained ward personnel exercising adequate supervision of apparatus and the postoperative routine of activity. Segregation of fracture cases as ward units is practically an essential to such organization.

The limits within which primary operative fixation can be safely done with benefit to the patient are here rather closely defined. They should be. In fact, it would be better were similar closely defined limits promulgated governing the use as well of pins and wires in the treatment of fractures.

If the requirements laid down in the preceding paragraphs are met, primary operative fixation of fractures of the long bones in adults is a safe procedure, giving sufficiently better end results on the

whole and great enough shortening of disability time for the injured to justify its use as the method of choice.

*Question 4.* How can these conditions be best established?

Any well trained surgeon, unless he be devoid of mechanical sense, can meet the requirements necessary as far as he personally is concerned with but little effort. By far the greater part of responsibility for success or failure lies in the organization and equipment provided for the carrying on of the work by the institution in which it is done. The individual who does the work will have to convince the institution that these requirements should be met. It can be done, and is being done. But until it is done in any given institution, no matter how excellent an individual surgeon may be, he may well say, "The operative treatment of fractures as a method of choice is neither a safe nor a worthwhile procedure"; but to make the statement truthful he should always add, "in my hands and in the institution in which I work."

If, in the *next* twenty-five years, there could be expended merely the time, money, and effort towards the establishment of these conditions that has been expended in the *last* twenty-five years in devising complicated ways and means of avoiding operative fixation, an optimum method could be much more widely used than it is today.

## SUMMARY AND CONCLUSIONS

Operative fixation of long bone fractures as a method of choice in adults holds theoretical advantages over closed methods of treatment.

These theoretical advantages can be safely translated into practical benefit to the patient sufficient to justify its use under certain definite conditions.

The necessary conditions, can be adequately met, and have been by a number of institutions, with resultant improvement in healing time, in length of convalescence, in length of disability time and in end results over those obtainable by closed methods.

Where the necessary conditions *cannot* be met, the procedure is not justified.

Where the necessary conditions *are not* met, it is possible in many instances to establish the proper set-up with no more difficulty than is today experienced in providing for means to avoid operation.

# FIXATION OF ONLAY BONE GRAFTS BY MEANS OF VITALLIUM SCREWS IN THE TREATMENT OF UNUNITED FRACTURES

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AN ununited fracture is one in which organic changes have developed which make union exceedingly improbable or impossible. If there is no evidence of union after the elapse of six months, a diagnosis of nonunion is usually justified. There are cases, however, in which nonunion may be definitely established in less than six months, and others in which union takes place after that period. In estimating the end results of treatment of ununited fractures, one should not include cases of delayed union.

For the successful treatment of these fractures, two requirements must be fulfilled: (1) secure fixation of the transplant, and (2) promotion of osteogenesis. The massive onlay graft secured with autogenous bone pegs has been employed by the senior author for approximately twenty years. The operation as originally designed by him was similar in mechanical principles to that of a procedure employed by Henderson, the differences being as follows: (1) A flat surface is created on each fragment for reception of the transplant, as little bone as possible being removed; (2) the endosteal or cancellous bone from the transplant is utilized as an intramedullary graft and is generously packed around the fracture site to promote osteogenesis; (3) only the cortical portion of the graft is used for fixation, as well as for osteogenesis, the endosteum being removed; and (4) autogenous bone pegs, rather than beef bone screws, are inserted for fixation of the graft. The details of the procedure are as follows:

An ample incision is made over the point of the fracture and the muscular and fascial planes are divided to the bone by sharp and blunt dissection. All scar tissue is removed from between the fragments. The periosteum over each fragment is incised longitudinally a distance of several inches, depending upon the extent and location of the fracture, and elevated from one-half to three-fourths' inch from the circumference. The soft parts, from which the circulation is derived, are disturbed as little as possible. The ends of the fragments

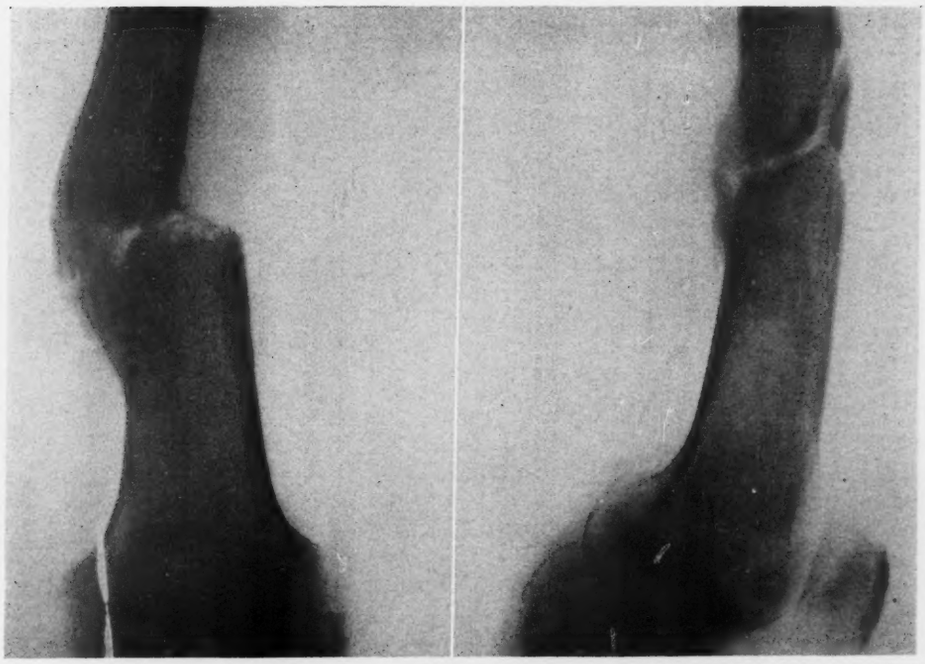

FIG. 1A. Nonunion of the femur, junction of lower and middle thirds, of six months' duration.

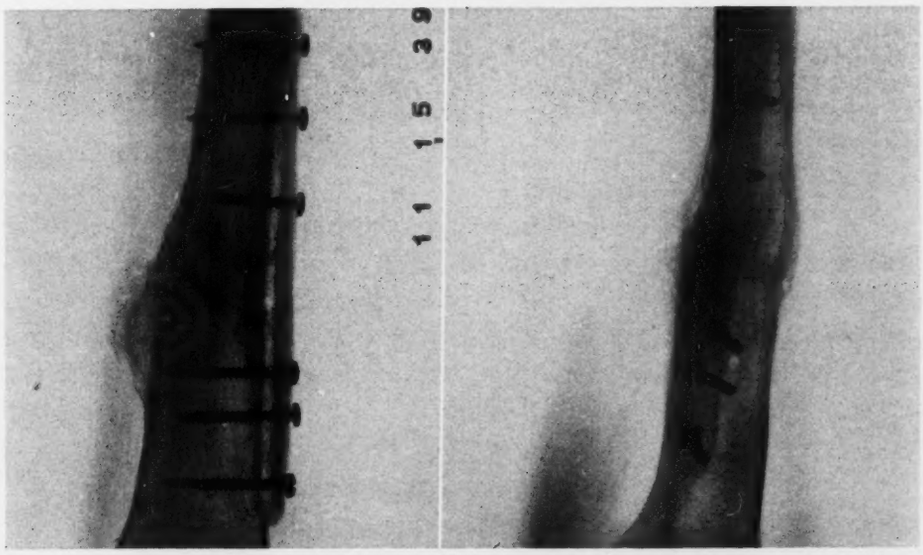


FIG. 1B. Union of the femur nine months following onlay bone graft in which vitallium screws were used.

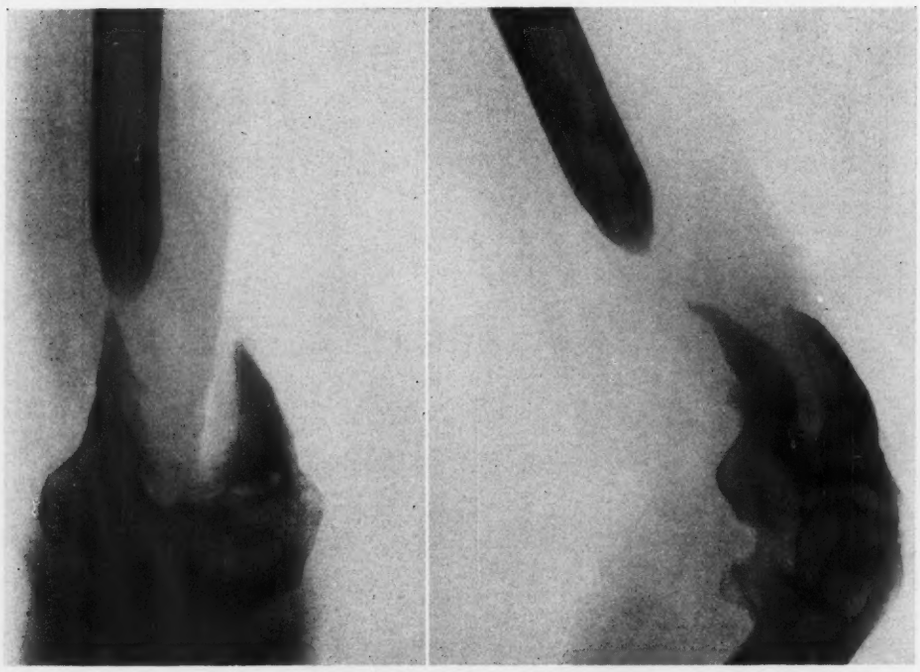

FIG. 2A. Nonunion of the humerus of seven months' duration, following compound comminuted fracture with infection and loss of bone substance.

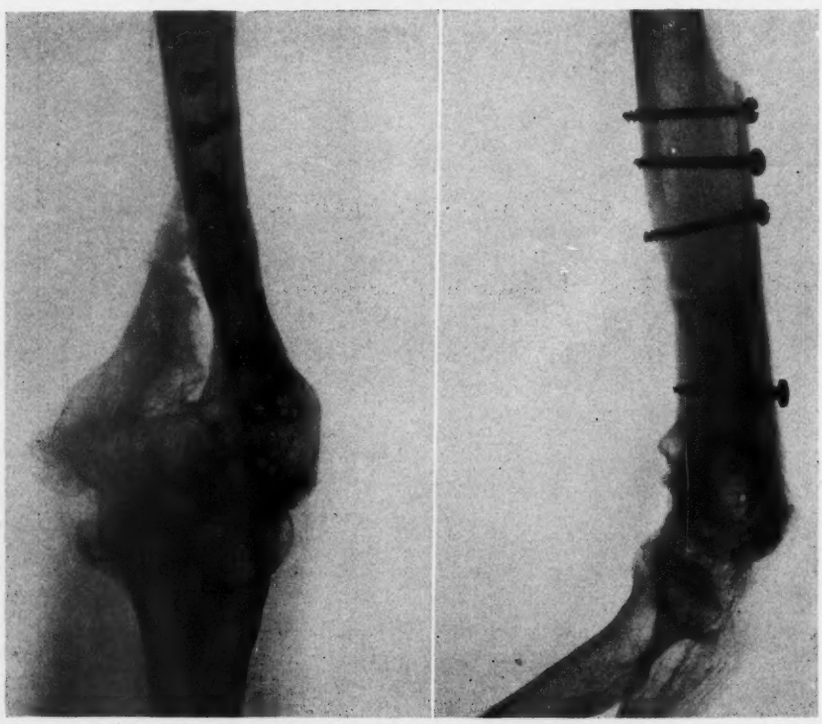

FIG. 2B. Solid bony union thirteen months following onlay fibular graft in which vitallium screws were used.

are freshened with a chisel or motor saw and the medulla of each is reamed out until normal marrow tissue is reached. Shavings are removed from the circumference until each fragment presents a con-

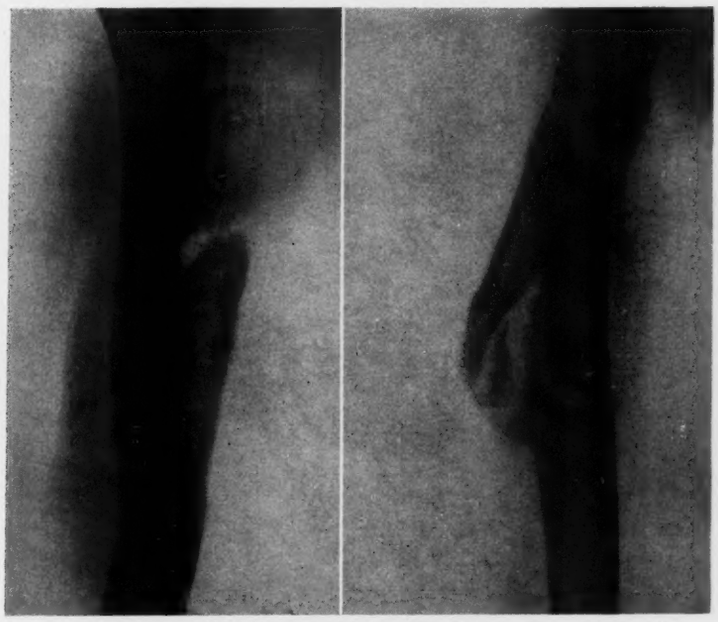

FIG. 3A. Nonunion of oblique fracture of the humerus, upper third, of two years' duration.

tinuous flat surface for a distance of three to four inches. A broad, flat massive graft of sufficient dimensions to insure firm fixation is taken from the tibia and, with a motor saw, is split longitudinally through the edge into two parts, a strong outer plate consisting of dense bone or cortex, and an inner layer, the endosteum.

As the fracture is reduced, a strip of the endosteum is inserted into the medulla of each fragment, bridging the fracture; thus, normal marrow tissue rich in osteogenic properties is restored. From the cortical segment of the graft six or eight nails of appropriate size are fashioned by means of a rotary file attached to a motor saw. A metal gauge is used for measurement. The strong outer plate is placed on the flat surface of the bone across the fracture site, and three or four holes are drilled through the graft and through each fragment, care being taken not to place the holes too close to the ends of the fragments. As each drill is withdrawn, an autogenous bone peg is inserted. The remainder of the endosteum is broken into small particles and placed with the "shavings" about the site of fracture.

The extremity is immobilized in a plaster cast or splint for eight weeks; thereafter, a convalescent brace is applied, usually in the form of a leather corset. If necessary, joints may be incorporated in

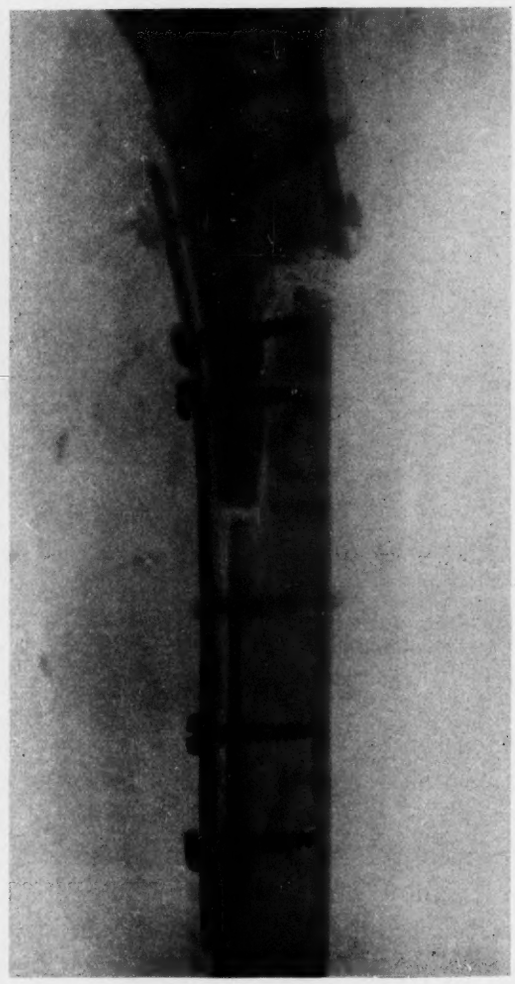

FIG. 3B. Postoperative roentgenogram shows onlay graft secured with four vitallium screws and two autogenous bone pegs.

the brace in order that motion may be instituted as soon as feasible. The brace is worn until consolidation of the fragments is complete.

In 1939, the senior author reported the end results of 261 onlay bone graft operations in which autogenous pegs were used for fixation.* Solid bony union was obtained in 235, or 93.6 per cent of these cases. Following publication of the work of Venable and Stuck,

* Campbell, Willis C. Onlay bone graft for ununited fractures. *Arch. Surg.*, 38: 313. 1939.

we adopted, in suitable cases, the use of vitallium plates in acute fractures requiring open reduction. It was soon learned that this metal was well tolerated by both the soft structures and the bone.

FIG. 3c. Solid bony union thirteen months following onlay bone graft.

The advantages presented by vitallium screws for the fixation of bone grafts for ununited fractures were then also recognized and the method was given a trial. The results were so gratifying that the use of autogenous bone pegs has since been almost entirely abandoned in favor of the vitallium screws. The screws have been found superior to bone pegs in that (1) better mechanical fixation of the graft is obtained, (2) a smaller amount of bone is removed from the tibia, and (3) the operative technic is materially simplified, the necessity for making the bone pegs being eliminated and the metal screws being easier to apply.

On the other hand, the use of vitallium screws possesses the following disadvantages: (1) a foreign body, though apparently inert, is introduced into the tissues, and (2) after the lapse of a sufficient period of time, the autogenous pegs become an integral part of the bone, which the vitallium screws cannot do.

To the present time we have employed vitallium screws for the fixation of onlay bone grafts in sixty cases. Forty-six of the patients were males and fourteen were females. The average age was 34.3

years; eleven of the patients were over fifty years of age. The average interval between the injury and the application of the bone graft was 16.5 months. Twenty of the patients had had one or more previous operations.

FIG. 4A. Nonunion of the humerus, junction of middle and lower thirds, of seven months' duration.

The location of the fracture in the sixty cases was as follows: tibia, twenty-two; humerus, fourteen; radius and ulna, nine; ulna alone, six; femur, five; clavicle, three; radius alone, one. Nonunion of the clavicle is rare and the unusual number observed in this group can only be attributed to chance. This is an illustration of the erroneous conclusions which may be drawn from a small series of cases.

In sixteen of the sixty cases the operation had been performed too recently for the establishment of union. In all of these, however, union will probably take place, since thus far no unfavorable signs have been detected. The fracture has failed to unite in three cases, although a sufficient time has elapsed since the operation. In one of

these union may yet occur; for statistical purposes, however, it has been classified as a failure together with the other two. Forty-one of the patients have bony union. Thus, in forty-four cases, ample

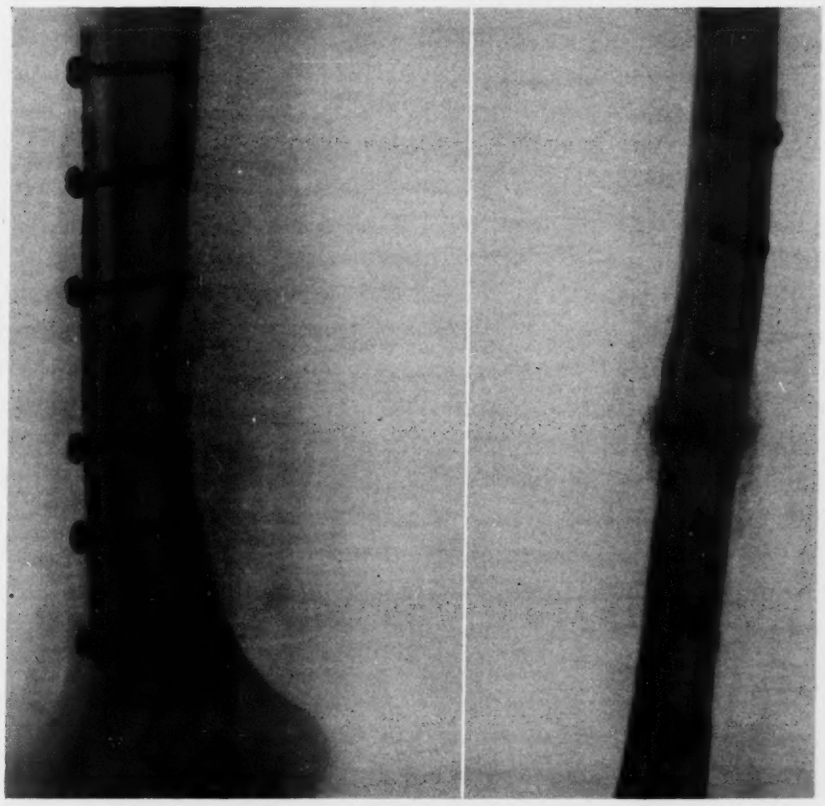

FIG. 4B. Onlay bone graft secured with vitallium screws, two months postoperatively. Union was clinically solid at this time.

time has elapsed to permit an estimation of the end results. Union is solid in 93.2 per cent of these, and in 6.8 per cent, including the one doubtful case, the operation was unsuccessful.

Of the eleven patients over fifty years of age, six have secured union. The operation was performed too recently in five to justify a statement as to the end results; there are, however, no indications that any of them will fail to secure union.

Fifteen of the patients gave a history of a previous infection, either following a compound fracture or following a former operation. In five of the fifteen the infection was relighted at the time of the bone graft operation, and, in addition, four other patients developed infection postoperatively. Six of the nine patients with infection obtained union. Two failed to obtain union. The outcome of the

operation in the third is still doubtful, as the graft sequestrated and was removed; at operation, there was only slight motion at the fracture site and it is believed that union will occur.

A modification of the onlay bone graft operation with fixation by vitallium screws has been employed by one of us (H. B. B.) in the treatment of congenital pseudarthrosis. A long graft is removed from the tibia of one of the parents and cut in half. After exposure of the pseudarthrosis, one homogeneous graft is placed on its medial side and the other on its lateral side. Long vitallium screws are inserted through both grafts and the affected bone for the purpose of fixation. The space about the fracture and between the grafts is filled with endosteum, which has been previously removed from the graft and from the upper portion of the donor's tibia. Union has taken place in all of the three cases of congenital pseudarthrosis in which this method was employed.

Union was secured in 93.2 per cent of the patients in this series as compared with 93.6 per cent in the series formerly reported wherein autogenous bone pegs were used. From these data, it would appear that the percentage of union will not be affected by the substitution of vitallium screws for autogenous pegs.

## CONCLUSIONS

1. The use of vitallium screws rather than autogenous bone pegs for fixation of onlay grafts simplifies the operation.

2. Better mechanical fixation of the graft is afforded.

3. Union is obtained in practically an equal number of cases by the two methods.

4. The theoretical disadvantage of introducing a foreign body has little actual significance, as vitallium is apparently inert in the tissues.

# THE USE OF VITALLIUM APPLIANCES IN COMPOUND FRACTURES

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IN the first World War there were, of course, many severe compound fractures with gross infections, osteomyelitis or gas gangrene which resulted in great loss of life and limb. To combat these infections, the débridement technic of Baron Larry was revived, the Orr method of adequate drainage was perfected and the Carrell-Dakin plan of wound sterilization was evolved.

Since the War, highway accidents have increased in frequency and severity, and fractures in industry have become so common that the treatment of compound fractures has become a major problem of traumatic surgery. In the past few years two new principles of treatment have been developed which supplement the earlier methods and which offer hope of constantly improved results. These factors are:

1. The proof that sulfanilamide acts as a local bacteriostatic agent when placed in compound wounds.

2. The fact demonstrated by us in 1936 that metals which are electrically passive (inert) in body fluids (electrolyte) can be used with safety in the internal fixation of fractures.

## I. LOCALLY APPLIED CRYSTALLINE SULFANILAMIDE

The discovery that sulfanilamide is an effective bacteriostatic agent has produced revolutionary changes in all fields of medicine and its use has become widespread. Shortly after it became available in this country, Bohlman tried giving the drug orally in cases of compound fracture to reduce the likelihood of secondary infection.[1,2] This prophylactic measure met with such success that it gained wide popularity. Later Bohlman,[1,2] Sinclair,[12] Chandler,[4] Nelson, Johnsrud and Johnson,[8] experimented with the introduction of pure crystalline sulfanilamide into compound wounds to enhance the bacteriostatic effects. This was found to produce high local concentrations of the drug in the wounds which prevented the development of osteomyelitis or gas gangrene. Sulfanilamide in a wound acts as a chemical deterrent to bacterial growth which thus permits the normal body defenses to overcome invading organisms.

In our series there have been fifty-six compound fractures which were treated with local application of crystalline sulfanilamide with infection of the bone in only two cases.[14] One of these patients had received a severe crushing injury of both bones of the leg, and the other had an extensive compound fracture-dislocation of the ankle, yet even in these osteomyelitis was not extensive.

As is well known, the exposed surfaces of wounds quickly become sealed so that bacteria are retained within the tissues at the wound site. Hence it is important that the infecting organisms must be prevented from growth in such wounds. A saturated solution of sulfanilamide in serum in a wound is nearly fifty times as concentrated as the amount of the drug which can reach the wound through the blood stream and is correspondingly more powerful. For that matter in spite of large amounts of the drug in a wound relatively little is absorbed into the blood stream. Since the body quickly builds a barrier against bacterial invasion the locally implanted sulfanilamide reaches the area where it is needed more rapidly than it does when given by mouth and is consequently more effective. The use of *x*-ray therapy to prevent the development of gas gangrene infection seems to be of value if it is used soon after the accident.[5,10] Locally applied sulfanilamide seems to be far more effective against the gas-forming anerobes.

## II. VITALLIUM FOR INTERNAL FIXATION

In all cases of compound fracture, thorough débridement of damaged tissues is of course essential and this includes changing of gloves, drapes and instruments when necessary during the operation. The wound must be flushed with large quantities of saline solution to remove scraps of foreign material and dead tissues and the fracture must be supported with casts, splints, skeletal traction or some other form of immobilization.

Since we had observed in 1937 that ununited fractures often healed following fixation with nonirritating vitallium plates, we began to apply them to fresh compound fractures through débrided wounds. The wounds were then packed open with 5 per cent xeroform gauze after the manner of Orr. Subsequently, the extremities were supported in the usual plaster casts or splints to immobilize the involved bone and the adjacent joints. (Figs. 1, 2, 3 and 4.)

We found that these wounds filled in rapidly with healthy granulation tissue while the bone healed normally. However, they often healed by scar formation which resulted in skin adherent to

the bone. Therefore, about two years ago we undertook to insert the plates and screws through a clean incision away from the contaminated area and to treat the wound sites separately. This caused

FIG. 1. Compound comminuted fractures of both tibiae. Right treated by application of vitallium plate. Left treated by skeletal traction which resulted in much less satisfactory result.

better healing at the operative site while the bone united and the open wound filled with healthy granulation tissue. The end results have been much better because fractures have healed with a minimum of delay or deformity:

| | |
|---|---|
| Total compound fracture cases | 102 |
| Treated by *x*-ray (prophylactic) | 28 |
| Developed gas infections | 0 |
| Gas gangrene cases treated by *x*-ray | 3 |
| Subsequent amputation | 1 |
| Death | 0 |
| Treated by crystalline sulfanilamide | 56 |
| Bone infections | 2 |
| Delayed unions | 2 |
| Nonunions | 0 |

In a recent study of 1,227 cases of all types in which vitallium appliances were used by sixty-one surgeons, we found that several others had been using vitallium plates and screws in compound fractures with equally good results.[3,6,21] Of all fractures of all types

A B

FIG. 2. A, compound comminuted fracture of left patella. B, wound débrided and fracture secured with single vitallium screw. A simple and effective method of treating patellar fractures.

A B

FIG. 3. A, compound fracture of both bones of the lower third of the leg. B, fracture fixed with two vitallium screws. Wound packed open with xeroform gauze.

treated with vitallium appliances 92.6 per cent gained solid union, 3.8 per cent showed delayed union and 3.6 per cent resulted in nonunion. If infections developed or if the fractures failed to heal

A B

FIG. 4. A, compound comminuted fracture of both bones of the leg at the junction of the middle and lower thirds. B, wound débrided; fragments anchored with vitallium screws and wound closed. Solid union and perfect alignment four months later.

the surgeons invariably reported "the metal was not at fault." Two and three-tenths per cent of the failures were due to technical troubles in the operation.

Therefore, we find once more that the presence of an inert (passive) metal does not interfere with the healing of damaged or infected tissue or cause any "foreign body reaction." In the very few instances in which osteomyelitis developed about screws it seemed to be due to the bacteria carried into the bone by them, because healthy bone healed in about the appliances after the infection subsided.

To be sure we do not favor the indiscriminate plating of all compound fractures since many can be adequately immobilized with

Kirschner wire traction or other forms of fixation. The need for internal fixation depends upon the type of fracture, the difficulty of reduction, the severity of the injury, the condition of the wound, etc. In this, as in all decisions, conservative surgical judgment is a prerequisite.

Sulfanilamide placed directly in compound wounds provided a powerful deterring effect against growth of the contaminating organisms. Vitallium alloy has made it possible to use internal fixation in compound fractures so that the bones are held in the best possible position for good union. These developments by themselves or in combination with others offer invaluable aid in the modern treatment of compound injuries.

### ELECTROLYTIC EFFECTS OF METALS IN BONE

Since we demonstrated four years ago that electrolysis must be eliminated from metals used in bone surgery this fact has become widely accepted.[17–20] Even the proponents of other alloys are beginning to speak of "pacification" of them by the creation of a protective molecular veil or the addition of molybdenum to "18-8" steel to inhibit the passage of electrons.

Sherman explained in a recent article that when his vanadium steel plates are applied to fractures a sinus may persist which requires removal of the plates and screws.[11] He added that the metal he used in splinting compound fractures "complicates the massive osteomyelitis." Moreover, " . . . the objections to vanadium steel have been overcome recently by the production of a new stainless steel (18-8 with molybdenum) . . . which will not corrode in the presence of sodium chloride. . . . " He was opposed to vitallium because he said it was a brittle cast metal "and contains air bubbles." Even though he stated that monel metal and duralumin corrode and "effloresce" in the presence of saline solution, Sherman denied that electrolysis could occur "when like metals are used." And finally he describes how infected wounds "usually cicatrize leaving one or more sinuses leading to the steel screws" and "this is due to corrosion or oxidation of the steel."

The sinuses leading to the steel screws indicate that an alloy is being used which has sufficient electro-activity to irritate tissues. Since electrolysis accompanies corrosion it is this action which erodes bone and causes chronic drainage. The abandonment of the highly electrolytic vanadium steel removed a great source of irritation of tissue and erosion of bone. The "18-8" stainless steel to which

molybdenum has been added is far less irritating than vanadium steel but it is incorrect to say a "like metal" is being used. Instead four metals (iron, chromium, nickel and molybdenum) are in combination and until they are more perfectly united to resist the passage of electrons there will continue to be some electroactivity about them. Uhlig and Wulff at the Massachusetts Institute of Technology have studied passivity of metals and have apparently found limitations of the oxide film theory.[15] They reported that the addition of molybdenum to "18-8" stainless steel tended to complete the atomic lattice and so increase the resistance to corrosion. However, this did not produce a completely passive alloy.

Hudack, in collaboration with Darrach and Murray, has pointed out that vanadium steel causes local irritation and erosion of bone which often requires its removal.[7] As a substitute he proposed the use of high chromium-low nickel steel as recommended by Jones and Lieberman.[9] He remarked that if this steel is highly polished and is "passivated" in nitric acid it may gain a molecular chromic oxide coating which resists corrosion. Nevertheless, in the forty-one cases he reported plates and screws were removed in twelve because of persistent sinuses, insecure fixation, local irritation, pulling out of screws or corrosion of the metal. He concluded that this metal will be adequate when "certain requirements" are fulfilled.

## THE IDEAL METAL FOR INTERNAL FIXATION

The "certain requirements" which must be fulfilled in any metal are passivity in body fluids and hence freedom from electrolytic irritative tissue effects. As we have frequently stated, a positive proof of electrolytic action (or "non-passivity") in the body is the ability to recover constituent metals of an alloy from the tissues adjacent to it. Chemical examination of tissues and fluids which have been in contact with the metal will reveal the presence of metallic ions corroded from the alloy. Thus far only vitallium is sufficiently passive in body fluids to cause no disintegration or release of metallic ions into the tissues.

We have stated before that *the amount of electrolytic disintegration of metals and consequent erosion of bone seems to be related to the current flow* recorded in a microammeter when the metals are combined with a third metal as an anode in sodium chloride. In other words, an alloy which produces many microamperes of current will produce much erosion of bone and the metal itself will disintegrate in the tissues. Thus the metals vanadium steel, duralumin, Dow

metal, etc., which cause destructive changes in the body produce more than 200 microamperes of current in saline. Stainless steel ("18-8") which is better tolerated by the body produces a reading of

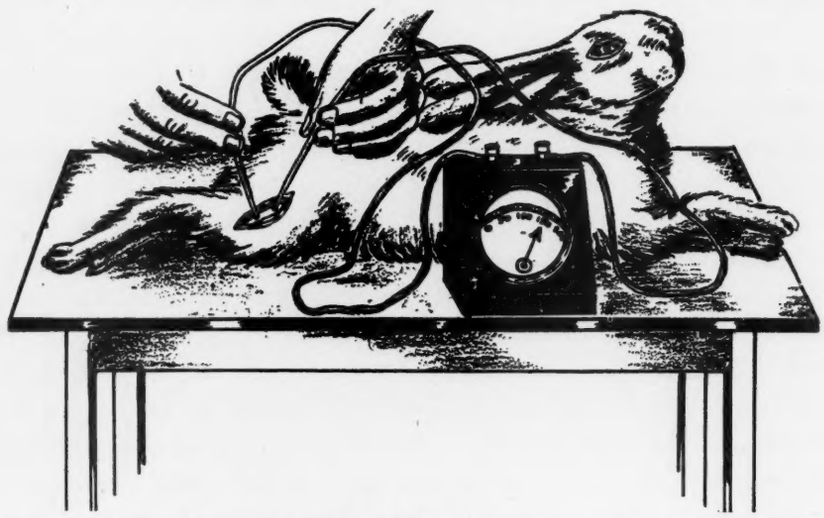

FIG. 5. Diagram showing contact being made between stainless steel screws in leg of experimental animal. Micro-ammeter shows relatively large amount of current produced.

FIG. 6. Diagram showing contact being made between vitallium screws in leg of experimental animal. No current flow demonstrable on the micro-ammeter.

50 to 100 microamperes. "18-8" stainless steel which has been "passified" with nitric acid causes still less irritation of tissue and a reading of 10 to 20 microamperes. Vitallium which causes no reaction in the tissues produces a reading of 1 to 2 microamperes momemtarily and then 0 amperes. (Figs. 5 and 6.)

While vitallium is the most inert alloy now used in bone surgery, we are experimenting with a recently developed alloy which seems to be approaching it in passivity. Our main interest has always been to discover an alloy which is completely nonelectrolytic and hence nonirritating in the body and at the same time malleable enough to be machined.

Experiments with "19-15" steel in which the nickel-chromium proportion is altered and molybdenum added seem to point the way toward the ultimate hope of a malleable yet passive alloy. More than a year ago we experimented with plates and screws of this new material and found that they produced only 3 to 5 microamperes of current. Screws and plates of this alloy were placed on the bones of dogs while similar vitallium plates were placed in opposite legs for controls. At the end of sixty days there were no evidences of corrosion of either metal or irritation of the tissues. Nevertheless, traces of nickel and chromium were recovered from the tissues adjacent to the "19-15" metal which shows that even this is not completely passive in the body fluids. Two similar cases of patients with malunited fractures of the shaft of the femur were operated upon and vitallium plates and screws placed in one while plates of the new metal were placed in the other. After a year there has been no appreciable clinical or *x*-ray difference between the two cases. The time seems near that a material will be developed which is sufficiently passive to be used safely in the body and which, unlike vitallium, can be machined.

Such developments should be closely followed but we must reemphasize that no alloy is universally adaptable to bone surgery unless it is completely passive in body fluids. This is especially important in the treatment of compound fractures, for here of all places irritation must be reduced to an absolute minimum. Absence of electrolytic irritation makes it possible to use vitallium plates and screws in compound fractures without such corrosive manifestations as erosion of bone or sinus formation. For the time being this is the only alloy that can be used in compound wounds with perfect safety.

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## DISCUSSIONS OF PAPERS OF DR. MURRAY, DR. CAMPBELL AND DR. VENABLE

Kellogg Speed: My discussion really covers only two of the papers. The first is that of Dr. Campbell

Assuming that the only autogenous graft is used for a fracture failing to unite and which has been opened, pared down or guttered for the purpose of attaching the graft, we can conclude that the field of the fracture has been reduced, as much as lies in our power, to conditions resembling those of a fresh fracture. To obtain bony healing there must follow fixation and immobilization of the part until bony union has developed.

In my experience I have never found in shaft fracture of long bones an ideal method of attaching the bone graft onto the host to establish real fixation. Absorbable material certainly will not hold it. Wedging beneath guttered edges may hold in some instances. Oldfashioned metal screws of doubtful metallic origin and producing electrolytic reaction, have failed and bone pegs or screws have lacked in tensile strength and lasting qualities.

With the advent of a nonelectrolytic reacting metal alloy, firm apposition and fixation, as great as that obtained in applying a metal plate, can be obtained. Our choice for this fixation must lie in meticulous boring of the transplant and its transfixation with cortex-to-cortex fixation into the host bone as in applying a metal plate. Vitallium, electrolytically inert, may well be used. I have seen a few vitallium plates and screws which became broken during clinical use and cannot be sure whether those breaks were caused by the brittleness of the metal or the presence in it of air bubbles, as claimed by Sherman.

Sherman favors stainless steel, an alloy made of high chrome, low nickel, and molybdenum, which has a high tensile strength and which, when properly machined, affords no electrolytic reaction to sodium chloride or hydrochloride solution. In practice I have been using either vitallium

or the stainless steel screws, in a few instances mixing them. Observation on these patients to date shows no untoward reaction.

In addition to considering the chemical reactions about screws, we must not forget the mechanical necessity for adequate external splint fixation to guard the screws against cross- and rotation-strain and absorptive atrophy of bone along these tracks from continued or overgreat pressure until bony union has occurred.

As for Dr. Murray's paper, "operative treatment of fractures" may be a misnomer. Could we not say "operation in the treatment of fractures," because the operation often enters into at the most only two requirements in the care of fractures, namely, apposition of fragments and fixation.

Fixation acquired by operation is, however, often inadequate to support limb weight, and must be supplemented by external splintage and fixation of a high degree of excellency, because in case of failure of the method, the blame may quite wrongfully be shifted back to the operative portion of the case, when it really lies in inadequate aftercare.

We must look at operation in treatment from a broader standpoint, not merely as surgeons working in the protected cloister of our own too attentive hospital, but from the standpoint of treatment everywhere throughout the country, in order that we may set a proper pace and a good example.

In general, then, more care should be exercised, and better attempts made by all physicians in the care of fractures, without the intervention of the factor of operation. There remain many instances and some well recognized types of fractures which require operative help from the very start. These I am sure you can readily call to mind.

Operation is, in my experience, required more frequently in the neglected fracture often seen late after injury, than it is in recent fracture. Failure to gain proper apposition and subsequent immobilization, particularly after shaft fractures in adults, require operation. We should not delay in giving this help. Some instances in childhood, especially near the joint surfaces of long bones, similarly may be offered operation early, and their progress after mishandling may be hastened and bettered by operation.

One virtue the surgeon must cultivate is patience in his handling of the fracture after operation, and not feel that simply because he has operated, cure will surely follow. I believe there is an undue amount of fear about immobilizing fractures around joints, but it is far better to keep them quiet a long time and minimize the amount of rebellious reaction and detrimental new bone formation about the joint than to attempt too early motion with disastrous results.

I had no more idea of what Dr. Murray was going to say than you had, but you see that I know him well and that I understand his thoughts, and I concur very heartily in what he has said.

GUSTAV F. BERG (Pittsburgh, Pa.): I was especially interested in the summary just given by Dr. Venable, because I believe he is delving into a

field that has been comparatively unexplored from the standpoint of electrolysis and corrosion. It is true that we have used metals of various types for a considerable number of years, in achieving the fixation of compound fractures, but it is also true that the last word has not been said.

Dr. Venable has very learnedly and logically set forth his bases for the use of vitallium plates and appliances, and his findings are of untold worth to the profession.

We will all agree that the end result desired in the reduction and healing of compound fractures is threefold: (1) A strong fixation which insures perfect weight-bearing alignment and good function; (2) the elimination of the dangers of infections and their end results; and (3) a lifetime use of the injured part.

In my experience in the use of plates, screws or nails, resort has been made to various types of steel plates and screws; chief among these are the ones designed by Dr. Sherman, of Pittsburgh, in 1910, the Lane plate, the pioneer Lambotte appliances, and an appliance which I use occasionally in types of compound fractures, known as the Smith clamp.

In using the Sherman vanadium alloy plate for a period of twenty-nine years, I have found that the vanadium steel plates achieved a rigid fixation. It does not submit to the vibrations of the body. It does not interfere with the formation of reparative callus, nor does it produce an electrolysis or corrosion, sufficient in character to become the basis of a biochemical or corrosive change.

Metallurgical constituents of the vanadium plates are that the steel for both plates and screws shall be chromium-vanadium steel, conforming to the following requirements as to chemical compositions:

| | Per Cent |
|---|---|
| Carbon | 0.45–0.55 |
| Manganese | .50– .80 |
| Chromium | .80–1.10 |
| Phosphorous not over | 0.040 |
| Sulfur | .045 |
| Vanadium not under | .15 |
| Desired | .18 |

The plates and screws, after forming, shall be heat treated to a hardness of not less than 43 or more than 53, as determined by the Rockwell hardness tester using the C scale and the 150 kilogram load on the diamond cone penetrator.

| | |
|---|---|
| Chromium | 18 per cent |
| Nickel | 8 per cent |
| Molybdenum | 1-V-38 |
| Rockwell hardness | 1-C scale 35.3 per cent |

Here are two screws that have been in the solution for a certain period of time, and they are presented for your inspection. The dates are on these.

One is dated December 26, 1939, and the other is dated February 6, 1939. I would like you to show me where there is any evidence of corrosion on the screws.

The end results achieved with the Sherman plate have been most successful, and I, therefore, believe that the use of the vitallium alloy plate appliances adds another efficient means of assistance in the treatment of compound fractures.

It is my belief that the matter of desired fixation is due less to the type of plate used and due more to the method of application of a plate to the fractured ends of the bone.

I believe that sufficient care is not used in holding the bone fragments immobile, and in holding the plate just as immobile, drilling the correct size of the hole. The one I use is the standard Brown and Sharpe one-thirty-second of an inch drill, and the screw which is to be used should be a tapping screw one-thirty-second of an inch oversize, and should be properly countersunk into the bone plate which has been used. That is very important, the drilling of the hole and the proper placing of the screw.

When all the screws are in place, they must be firmly snugged up so that there is no play between the bone and the plate and the plate and the screws. There must be no stripping of bone thread, and at no time is rough handling of the bone permitted. I should like to see the surgeon who has the mechanical ability to place properly a holding forcep on a bone, then hand it to his assistant, and his assistant be able absolutely to immobilize the same, while the surgeon drills the necessary number of holes. By the time this is done, how much of the bone that would fit the screw has been destroyed? What is the result? As the result of mechanics used in drilling and inserting the screws, considerable bone has been devitalized, and as the result of this devitalization, there is an absorption of bone which takes place around the screws, and as the result of this absorption the metal of which the screw is composed is accused of causing an electrolysis.

It is not permissible to overheat the bone in the act of drilling the holes by the use of high speed motors. I have found in my own experience that a combination bone clamp must be used in order to meet the above requirements.

Without any attempt to appear immodest, I must say that I have achieved this complete immobilization with a bone clamp which I designed. This is a combination clamp which comes apart and these are individual clamps, use one on one fragment and one on the other. After your bone is gripped by the instrument, the cross-bar is inserted. This is put on and it makes no difference where your fragment is. Your traction screw is then applied, and you start your correction of your overriding. Any lateral deviation and misplacement is corrected in the handle. If any one is interested in the clamp, I present it for your inspection.

I understand that our colleague, Dr. James H. Jackson, has designed a clamp with which he is able to secure the same result.

You can see that it is my thought that it is not much the type of plate used, as the manner in which it is used, that determines whether or not a perfect fixation shall be achieved. If, after a period of twenty-nine years, I have not been troubled with the danger of sufficient corrosion caused by the use of the Sherman plate, then I believe the proponents of the vitallium plate must admit that we have not suffered from the electrolysis or corrosion sufficient in character to bring about a destructive corrosion by the material used, and have had no interference with the union of fractures, as the result of the material used.

The absence of absorption of bone after the use of vanadium plates, in many thousand cases, during the past twenty-nine years, also must draw an admission that the vitallium plate, screw and appliances are not alone in the field. I have not been very much interested in the use of vitallium appliances, because of the uniform good fortune with the materials at hand.

It has come to my attention that there has been some criticism of the vitallium plate, and this criticism has as a basis certain metallurgical deficiencies. Dr. T. A. Carnes, of Massillon, Ohio, surgeon to the Republic Steel Company, has taken *x*-ray films of vitallium plates and screws, and has found concealed gases and air bubbles in both plates and screws. Some of these bubbles have been located at the head of screws, making shearing of the head a great hazard.

It is admitted by anyone familiar with metallurgy that air bubbles are not desirable, and, further, that all metals are electrolytic or corrosive to some extent.

In closing, may I again congratulate Dr. Venable for his invaluable aid to the profession. I will add that after the close of the meeting I would be pleased to demonstrate *x*-ray films of a patient operated upon twenty-nine years ago for a compound fracture of the right humerus, *x*-ray films and pictures of a patient operated upon for a supracondylar fracture of the right humerus twenty-one years ago, the bone plate still being in proper position; and the patient having absolutely no discomfort or interference with normal function. This patient was operated upon at the age of thirteen. This was not a compound fracture, however, a case demonstrating the use of the Smith clamp in compound fracture.

I should also like to demonstrate the combination clamp which is, I feel, of great assistance in the treatment of fractures. I also wish to present two test tubes containing the new type of molybdenum stainless steel screws which have been immersed in hypochloride .05 since December 26, 1939.

Gordon M. Morrison (Boston, Mass.): Very briefly I should like to mention one or two points regarding the discussion of closed versus open treatment of compound fractures. It seems to me that there is a certain class of case where the patient is badly shocked, and we know shock and sepsis go hand in hand. In that type of case, or that classification, the closed treatment, following irrigation, should be definitely out.

One other factor that has given me trouble in the past and which I see other men getting into trouble with regularly, is that of the pinpoint compound fracture. Spinning an iodine gauze swab into pinpoint compound fractures will take care of some of them, but there is an awfully large percentage that go rankly septic, and then you have real trouble on your hands.

It seems to me that we ought to keep after the men who do not attend meetings of this sort and educate them up to that simple fact.

The manner of irrigation is important; it has a technic.

Dr. Griswold brought out what I think is a mighty excellent point, namely, that the tip of the irrigating apparatus should be placed in the bottom of the wound and the wound should be flushed from the inside out and not from the outside in. That is so self-evident that it hardly seems worth while to bring up, but in going around, occasionally one sees someone merely slopping soap and water or salt solution into the wound.

In those cases in which we have used vitallium screws for fixation, cortex-to-cortex, or used vitallium plates, we have not had any trouble with their becoming loose. It has seemed to me that there is an added factor of holding security with the vitallium screws. This holding security is mighty important in the clean cases, more so in the septic cases. I believe that Dr. Venable has made a great contribution to bone surgery.

KENNETH M. LEWIS (New York City): I just want to show one slide illustrating an onlay bone graft in a complicated case, but before showing that, I cannot help but think that some of this discussion takes some of the New York men back to a trip that we made to Pittsburgh about five years ago. Dr. Murray will remember that trip very well, and I am rather convinced that there are many roads that lead to Rome.

I remember at that time Dr. Sherman was very enthusiastic, as he had been for many years about the routine plating of fractures of the shafts of the long bones. We men in New York did not believe it could be done. Dr. Murray at that time did not think it could be done. Dr. Murray decided when he got back to New York, that he would try to duplicate Dr. Sherman's work and, needless to say, he has done a very excellent job.

I should like to say that at Bellevue, where we are working in a large city hospital, where we cannot possibly have the set-up that Dr. Sherman has and that Dr. Murray has at Presbyterian Hospital, we believe that some of the thoughts Dr. Murray has been expressing this morning should really be given a great deal of serious attention. A lot of open bone work on fractures, when necessary, can be done, and can be done with safety, if the proper organization and the proper care of details are taken care of. A special operating room for bone cases and a modified type of Lane technic are essential. Since we have adopted that on practically all services at Bellevue, we have found our incidence of infection has been less, that the

job can be done, and I think the thing Dr. Murray wanted to get across, and that many of us ought to try to appreciate, is the fact that it can be done and is not so much the question of who operates on the fracture as it is the invariable attention to details and organization which Dr. Sherman over many years has almost made classical.

I want to show this slide because it happens to be a complicated case. This man had his arm projecting out of a bus window and sustained a fracture of the humerus, together with an anterior dislocation of the head of the radius, a muscular spiral paralysis and a compound fracture of the upper third of the ulna. He was treated with traction. His humerus united. It was impossible to reduce the dislocation of the head of the radius. The head of the radius was excised, and subsequently, in about two months, there was a pseudarthrosis which developed at the site of the fracture in the ulna. The ulna was operated upon. The eburnated bone was quite extensive, which left a defect that can be seen.

The upper fragment of the ulna was in two pieces. I noticed in many of the films shown with Dr. Campbell's paper the number of screws used in the plates. I will admit here we have only one above and one below, which are too few. I am wondering whether two above and three below, provided they go right through to the cortex, are necessary.

Only two screws were used here because the upper fragment was in two pieces, and because of this we were afraid that in putting in two screws we might split it and spoil our end result. Even so it was simple to use an onlay graft with one screw above and one below. It has been retained and the patient has an excellent end result. An inlay graft would not have been satisfactory; a medullary graft could not have been used because the medullary cavity did not run up into the upper fragment.

DERYL HART (Durham, N. C.): I will say only a few words. I believe that in our work, and I think we have conclusively proved in our hospital, that the air is an important source of infection in any open wound, particularly in those involving bones and joints.

For a period of four to five years we had a great deal of trouble with infections in clean operative incisions and these could not be eliminated by the most rigid technic as we then understood aseptic technic to be. We had a number of carriers of the Staphylococcus aureus in the nose and throat (at times as high as 80 per cent of the general population, and also the operating personnel). This organism caused the greatest trouble, both as regards number and severity of infections.

By January 15, 1936, we had carried out preliminary tests on bacteria and animals to prove the efficiency of certain wave lengths of ultra violet for killing bacteria floating in the air or on a petri dish, had demonstrated on animals that wound healing was not impaired, and had equipped an operating room for air sterilization of this method. I would like to give you certain statistics, which I have just finished compiling.

From July, 1930, until January 15, 1936, out of a total of over 15,000 operations, we had eleven deaths from infections in clean primary incisions, all of these patients having operations of great magnitude. There were four thoracoplasties, three bone and joint operations, one radical mastectomy, two craniotomies and one radical dissection of the glands of the neck for carcinoma. All these patients except three had a septicemia with the same organism that caused the wound infection. The two cases of brain surgery did not have a septicemia but had an associated meningitis, so there was only one death without an associated septicemia or meningitis.

Since January, 1936, we have performed large clean operations (laminectomies, craniotomies, thoracotomies, radical mastectomies, arthroplasties, hernioplasties, etc.) in a field where the air is sterilized. Out of a total of 25,000 operations, we have had 2,500 performed in relatively sterile air, and out of this group of cases we have had not one death from infection.

Our deaths from infections in clean operations stopped sharply when we reduced the contamination of the air as a source of infection. At the same time, we reduced our infection rate in general surgery, and the surgical specialties, from approximately 4 per cent, most of them mild but with an associated severe septicemia and fatalities as I have indicated, to less than one-half of 1 per cent, most of which have been stitch abscesses. Furthermore, our postoperative temperature reactions, both in duration and elevation, have been reduced by from 30 to 70 per cent, being greatest for procedures of the magnitude of an extrapleural thoracoplasty and least in the operations of less magnitude such as hernioplasties. Furthermore, the amount of temperature reduction has also corresponded to the amount of reduction in the air contamination.

From January until June the air contamination is relatively high, dropping quite low during the summer months and rising against during the fall. In the case of thoracoplasties without radiation the curves found by plotting the average elevation of temperature or duration of temperature by months follows roughly a similar form. With radiation, however, the greatest reductions both in temperature elevation and duration, have been during the colder months so that the former curves are reversed, being lowest in the cooler and highest in the warmer months.

During the summer months when the air contamination is low, we have obtained little reduction in the temperature reaction, and it is our impression that contamination of the wound with bacteria-laden perspiration is one important factor in the production of this reaction.

I might say further that all members of the Surgical Staff (including the Surgical Specialties) have been given complete freedom of choice as to the use of ultra violet radiation. It is used by all of them with the exception of those on the nose and throat service who do not perform operations in which radiation is indicated. We have three of our five larger operating

rooms equipped for air sterilization and the demands for its use are so great that we are now having the fourth room equipped.

GROVER C. WEIL (Pittsburgh, Pa.): I can not help but take the opportunity of subscribing to some of the very excellent remarks in the papers presented, having come from Pittsburgh in an industrial center where we have long practiced and pioneered in the work of open reduction. However, it must not be thought that all fractures are reduced by the open method. We have long since, of course, realized the importance of instituting proper surgical measures or methods in each individual case.

Dr. Murray, I do believe, rather minimizes his own particular ability. He is rather timid about it, nevertheless; he has played the great rôle in effecting his organization, which is most important and which has brought about his marvelous results.

Just a word about compound fractures, going back to Dr. Speed's dictum of fixation, retention and return of function. We have always believed in the great importance of this. It represents a major surgical procedure, and the time period from the injury to the institution of your method is of the highest importance.

In times past I have seen many tragic deaths from gas bacillus infection; and when one considers the potentially dangerous effect of this organism within such a relatively short period of time, one can realize the importance of the institution of early treatment. We consider as one of the most important phases of the treatment of the compound fractures, the institution of early surgical interference.

We carried out the open method long before Orr popularized it. In fact, of course, he made a real contribution. With the cases left open with proper drainage following débridement—what we call sensible débridement after fixation—with, as a rule, the Sherman bone plate, it has been our observation that severe infections have been reduced to a minimum where the wound was supplied with ample drainage and dressings are delayed for weeks, followed, of course, later by secondary closure and granulation.

I have become very much impressed with the use of sulfathiazole. Dr. Venable brought out the use of sulfanilamide, but we have found sulfathiazole, particularly the sulfamethylthiazole, which we used first, was perhaps the most marvelous chemical agent we have ever used. We insufflate it in the wound, diffuse it about thoroughly, and, as Dr. Venable brought out, its application in the wound brings about a very low blood level; but its character and nature is that it is bacteriostatic, has a bacteriostatic effect, which is certainly of great importance, and we have recently been able to close up compound fractures after introducing perhaps anywhere from 100 to 150 grains. We have been able to close up these wounds without evidence of any infection.

It is too early as yet to speak of it with authority but, nevertheless, in our hands, it has certainly given great promise.

ARNOLD GRISWOLD (Louisville, Kentucky): I should like to say a few things on sulfanilamide and sulfathiazole implantation in wounds, which may be somewhat at variance with one statement of Dr. Venable and Dr. Weil. We have found that we can raise the blood concentration with both of these drugs to quite high levels by direct implantation of 5 to 15 Gm. of the drug in the wound. Taking a curve of blood concentration every two hours, following implantation in muscular structures, the blood concentration hits a peak of six to nine in about twelve hours and dies off in about forty-eight hours. When the drug is used in the peritoneal cavity, the absorption is much more rapid, and the blood peak occurs in about four hours. Our highest concentration has been a peak of fourteen, four hours after operation, and we have seen cyanosis following implantation of sulfanilamide in the wound.

CLAY RAY MURRAY (closing): I have very little to say in closing except that I should like to comment on something said by Dr. Speed and referred to again by Dr. Berg, as emphasizing my own personal convictions. In my opinion the majority of the criticisms directed at the metals commonly used in the fixation of fractures as being responsible for failure to heal and for irritation in the tissues should be directed toward the technic with which these metals are applied and the lack of absolute fixation, rather than toward the chemical composition of the metal.

Any metal put into tissues which undergoes excessive strain because of lack of rigidity in fixation, or which is loose in the tissues, or which is applied in tissues which as a preliminary are badly traumatized, is going to cause trouble, not because it is metal but because it is a foreign body in an area of inflammation. The tissue fluid changes which occur as a result of that inflammatory process are per se sufficient at times to prevent bone formation at the site of a fracture. In fact, some fracture cases result in nonunion, as we all know, without the use of any metal. The inflammatory reaction at the fracture site, if it produces sufficient change in the tissue fluids to cause prolonged marked acidity, will cause delay or failure in calcification of the healing tissue.

I agree with Dr. Berg that it is probably not necessary to have complete passivity of the metal introduced. It is ideal, unquestionably, but from my point of view in the operative treatment of fractures as the method of choice, it is not only necessary to have a metal which in itself does not cause any appreciable disturbance, but it is also necessary that that metal be able to stand the strain of function postoperatively. Vanadium steel in our hands has not been able consistently to withstand the strain of function. The breakages were few, but they were very, very disturbing.

Vitallium has no reaction in the tissues. It is a cast metal and it would appear from what work we have done with the metal that it will not stand the strain of active function postoperatively in the form in which it has now, or up to now, been put out. In other words, I think Dr. Venable

and I, while I talk in terms of stainless steel of a certain type, and he talks in terms of vitallium, are talking the same language, and have the same ideal, and I think he will admit if ever a metal is discovered which produces no physiological change, and which at the same time has the flexibility and the toughness of the stainless steels, we will have the metal which fulfills all requirements. Vitallium is not that metal in my opinion.

One other thing I think is of importance: I do not believe we have a satisfactory criterion of tissue reaction unless it is checked by physiological results. The reactions caused by metal in saline and other solutions are not adequate evidence. As to use in the body, I think one has to produce evidence that a metal is not only electrolytic, but that the amount of electrolysis produced actually produces changes in a tissue. Changes in ammeters do not affect fracture healing. On the other hand, this is partly an academic question because of the amount of electrolysis induced will depend largely on what tissue is involved. Furthermore, it is into freshly traumatized tissue, further traumatized necessarily by whatever operative procedure is used, no matter how carefully it is done, that metals are placed. It is, therefore, necessary to have a test fluid of a very low pH. Experimentally we have been able to determine the pH of the tissues in vivo. A pH as low as 4.5 twelve hours after injury has been recorded. In that pH any metal is much more active electrolytically than in normal saline. For that reason I believe the approach to the ideal complete passivity is a very necessary thing, and I think the investigation which Dr. Venable has done is therefore of paramount importance; but if the principle of optional operation, based on the purpose of cutting convalescence time and lessening the economic cost of injury—if that principle is to be used—a metal must be developed which will both stand the strain of active function and remain inert. Incidentally, I think that covers also in a way the question which Dr. Speed raised, in which he said that postoperative fixation must be applied.

We can lay down as a definite rule for long bone fractures in adults that rigid fixation must be secured at operation if functional activity is to be allowed postoperatively. No case should be subjected to operation as the method of choice unless we are convinced that such fixation can be secured. We believe we have demonstrated that rigidity can be secured by a two-plane fixation, and that with such two-plane fixation postoperative immobilization in plaster is not needed provided the patient is kept in balanced suspension, adequately supervised. This does not mean a resident testing the apparatus at eight o'clock in the morning and again at eight in the evening; it means apparatus adequately supervised all day.

In any fracture in which the plate or screws or other fixation material gives inadequate fixation, external immobilization becomes necessary. If that case has been operated upon as the method of choice rather than by necessity, and postoperatively it is found necessary to incorporate the part

in plaster, it was a mistake to operate on the patient provided any more conservative measure would have secured adequate position.

The fixation problem is a very major one. Postoperative care of the patient is a very major thing.

Dr. Lewis, I think, expressed in very concise terms exactly my point in reading this paper; that is, that if in the hospitals of the United States the men who are doing fracture work will devote as much time, effort and money in developing the organization and equipment of their hospitals to a point at which this work can be safely done as they now devote to the devising of ways and means and apparatus to *avoid* operation on cases, the use of the operative treatment of fractures can become much more widely spread, with a great deal of economic gain and without any increased risk of either infection or death for the patient.

HAROLD B. BOYD (Memphis, Tenn., closing): I wish to thank Dr. Speed and Dr. Lewis for their discussions of our paper.

In regard to the possibility of breaking the screws, in this series of sixty patients, we broke two screws. This may occur due to two factors: First, a defect in the screw may occur in the process of casting. Second, the hole drilled in the bone may be too small for the screw. With this in mind, we are careful to have the proper size drill for the screw to be used. A slightly smaller drill is used where the screw is placed in cancellous or osteoporotic bone than when it is placed in normal cortical bone.

Dr. Speed has illustrated how the transplant may pull away from the shaft of the grafted bone. This occurred in a few of our cases in which autogenous bone pegs were used, but has not occurred in any case in which the vitallium screws were employed. Since the vitallium screws hold the graft securely, one should take special care not to apply the transplant under tension. Undue tension on the graft may cause it to absorb or break at the fracture site. The vitallium screws do not permit slight readjustment of the position of the graft, as seen in some cases fixed with autogenous bone pegs.

Dr. Lewis' criticism of the number of screws used is well taken. In our more recent cases, we have been using four screws in most grafts; however, we still use six screws when applying a graft to the femur. I do not believe that the use of two screws, as shown by Dr. Lewis, is adequate.

CHARLES S. VENABLE (closing): I do not think I made my point quite clear concerning sulfanilamide. What I said was "proportionately" and by "proportionately" I mean that if you give a patient 150 Gm. of sulfanilamide by mouth, that is a much more serious thing than if you put 150 mg. in a wound, and, of course, there is a proportionate change as it is taken up by the blood. What I intended to say was that proportionately it may be used in large quantities with reasonable safety.

I think that Dr. Berg and Dr. Murray, Dr. Sherman—in fact, I think we have all come around to talking exactly the same language. I have shown

you today the expectancy in using a material that is passive. I have been working just as hard to find, in testing many materials that could be milled, a steel that would have all of the things in point of strength that Dr. Murray requires, that is also as passive as vitallium.

It is impossible and impractical to talk about whether a metal is electroactive or not by putting it in a bottle of salt solution. I have some that have been in three or four years and still look pretty good, but you can probably recover the constituent metals after a certain length of time. Remember that the body fluids are different from just plain salt solution. You have other elements that have effect and more effect than plain salt. The crucial test of whether or not there is any irritation or any electrolytic action can only be had by the method of recovering one or more constituents of the material, so that your chemist may tell you what the metal is made of from his examination of the body or other fluid acting as the electrolyte. What we are all trying to do, in attempting to reach the same end, is to have material that can be cheaper, that can be milled, that can be machined and which will be consistently tolerated by bone and tissue.

I think there will always be a place in surgery for vitallium. Under the stress and strain of hip cups, in the first place it would have to be a cast object and not one machined; there are variations in the mechanics of creating the appliances we need. We are all talking the same language and all I hope is that we talk it so plainly that everyone understands we are striving toward the passivity of the material and trying on that basis to find the material that will then serve both purposes of strength and passivity without any fear of irritation, so that we can go to bed and go to sleep and not worry about what is going to happen.

# LOW BACK PAIN AND TRAUMA

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MAJOR back injuries sufficiently severe as to cause definite compression fractures of the lower dorsal or lumbar vertebrae, partial dislocations or fractures of one or more of the transverse or spinous processes or even fractures through the arches of the vertebrae usually are diagnosed readily by the history of injury, the physical findings and the *x*-ray proof of the condition. Practically always such conditions give immediate signs and symptoms of severe low back pain. In the majority of cases the above mentioned fractures are easily demonstrable roentgenologically just as are fractures in the long bones. However, in a goodly number of cases pre-existing conditions in the spine, both congenital and acquired, may so confuse the *x*-ray findings as to cause widely different interpretations as to the presence or absence of fractures.

When alleged injuries to the back occur without causing fractures or other bony pathology demonstrable by *x*-ray, our problems of diagnosis and the probable relationship to true injury become far more difficult. Here again, the congenital and acquired changes in the spine may furnish the roentgenologist and the surgeon theoretical, and often bizarre explanations for the cause of the low back pain. Often one surgeon claims that the condition has been aggravated by the injury, while another disclaims any traumatic responsibility for the condition. Consider, for example, the congenital anomalies of spina bifida occulta, the sixth and often atypically formed lumbar vertebra, the winged and elongated transverse processes of the fifth lumbar, the rudimentary rib of the first lumbar with its line of articulation frequently interpreted as a fracture, failure of fusion of the two parts of an arch with a defect so often called a fracture, or the spondylolisthesis which may or may not accompany the above condition and which is so frequently called traumatic displacement, and the numerous other anomalies which confuse the diagnostic picture. Consider further the acquired conditions in the spine which cause even greater controversy concerning the cause of the low back pain and the relationship to injury, for example:

*A.* Infectious spondylitis with its destructive changes, or the osteochondritis of adolescence either of which may cause changes in the intervertebral discs, and even narrowing of the vertebral bodies, the result of osteoporotic changes, which frequently are confused with compression fractures.

*B.* The osteo-arthritic changes in the spine usually called arthritis, but better classified as arthrosis, and which practically all authorities agree are changes typical of fair wear and tear. These changes are so uniformly found in the spines of older individuals that after fifty this is almost characteristic of a normal spine. Yet, when such an individual, after heavy lifting, develops a low back pain, there are those who invariably call the condition traumatic or claim that trauma aggravated an existing condition. Did the patient mow the grass or rake the yard the night before, or did he sleep in a draught, or did some barometric or other natural etiological factor, likewise causing his next door neighbor to have a low back pain that morning, have some influence in causing his condition?

*C.* Finally, herniation or rupture or protrusion of the nucleus pulposus is the newest condition to enter this field of controversy concerning the causal relationship between the low back pain and trauma.

We seem to forget that these congenital anomalies have been with the patient all his life. We forget that Schmorl, and others before and after him, found all kinds of degenerative and proliferative changes in thousands of spines examined, all attributable to the repeated, long continued traumatizing forces of fair wear and tear. We forget, as Beadle points out, that the supply of food stuffs to the intervertebral discs must be consummated entirely by diffusion through the minute spaces of the spongiosa. He states: "No wonder that the intervertebral discs show perhaps a stronger inclination to various forms of degeneration in advancing age than any other tissue of the body." It would seem just as logical to claim that a minor fall or overlifting aggravated a degenerative kidney condition or an arteriosclerosis, as to claim aggravation of a large majority of these natural degenerative changes in the spine. The fault lies with the majority of us who have sought a traumatic explanation for the subjective complaint of low back pain.

Low back pain is one of the commonest complaints known to the human race. For ages the back has been the happy hunting ground for the majority of cultists. The medical profession has awakened to this source of human suffering and has instituted many corrective

measures with excellent results. However, we must guard carefully lest our enthusiasm, especially for the surgical attack on low back pain, may carry us to such extremes that future generations may look back upon this surgical epoch with disapproval.

Trauma always has been one of the commonest etiological factors for disability. In this machine age the traumatic factors have multiplied excessively. With each succeeding decade, there is a growing tendency to ascribe the majority of low back pains to trauma. While a relative increase is undoubtedly true, yet the medicolegal and compensation factors are responsible for a high percentage of these alleged low back traumas. No portion of the human anatomy has furnished a more lucrative field for exploitation by lawyers and medicolegal experts specializing in personal injury suits.

Today there is a spreading wave of enthusiasm for the surgical attack of back pain. Coincidentally, there has been a marked stimulation for specialization throughout the profession. Justly these questions may be asked: Are the specialists in traumatic or orthopedic surgery causing too many of us to attempt to solve low back pain in the terms of trauma? Are too many of us overenthusiastic to evolve some new method of treatment? Witness just yesterday the invention of every conceivable type of back brace, and today the names already attached to various forms of back operations! Are specialists in other fields too prone to interpret the low back pain in terms of their specialty and proceed to operative intervention without first viewing the multiplicity of causes responsible for the complaint? The making of specialists and the increased technical ability to attack the human body surgically should involve a corresponding increase in general diagnostic knowledge and ability. Conversely, a broad knowledge in general diagnosis and in pathology, as related to every field of medicine, is absolutely essential for the best and most conservative specialist.

In no field of medicine is this so literally true as in the management of low back pain. Such management, to be honest and successful must be based upon: (1) A foolproof diagnosis of the cause; (2) the simplest method, whenever possible, of attacking the condition rather than some complicated method; (3) a treatment that will not enhance the seriousness of the situation in the patient's mind, for example, the chronic osteopathic patient with the proverbial dislocated vertebra; the back neurotic from too much so-called physical therapy—so-called because too often it is merely turning on the short wave for days and weeks; the chronic back case wedded to a belt or

back brace; and all the other numerous types of back neurotics; (4) avoidance of the treatment which cures the primary cause but leaves a secondary disability due to a wrong line of treatment.

Space will not permit a critical review of the anatomy of the spine and yet one must be familiar with this normal anatomy in order to understand certain variations not sufficiently recognized as potential or actual trouble makers.

The normal spine is composed of thirty-two centers, twenty-four of which are movable. Not infrequently the movable vertebrae are increased to twenty-seven. These extra vertebrae are usually in the cervical and lumbar region and are found most often in the long necked, narrow chested, flat backed, asthenic type of individual. They are significant because of the proneness of such individuals to have low back pain.

The vertebrae joined by their intervertebral discs have certain normal physiological curves where, according to Eben J. Carey, the line of demarcation between the normal and pathological is not fixed. These physiological curves can be divided into primary accommodation curves and the secondary compensatory curves. When considering low back pain, the primary lumbar curve is of great importance. The anterior convexity of the lumbar spine is biologically an accommodation curve so arranged as to help support the abdominal viscera. Its normal secondary or compensatory curve is noted by the straightening of the lumbar spines in forward flexion movements. When this normal lumbar curve becomes acutely lordosic (the angle between the fifth lumbar and the sacrum is abnormally acute), we invariably have a potentially *weak back*. When the convexity of this lumbar curve is lost or is reversed into a concave curve, we have the typical *flat back* or lumbar rounded back. This is the characteristic back in the great majority of individuals of the Stiller or neurocirculatory asthenic type, a large percentage of whom are prone to low back pain in the third and fourth decades of life. In addition, there are ligaments joining together the articulating processes of each adjacent arch, ligaments between the spinous processes and ligaments between the laminae. In low back pain these ligaments must play an important part when the normal physiological lumbar curve becomes abnormal.

There are five layers of muscles about the spinal column, adjacent and overlapping. Carey has demonstrated over 120 pairs of intrinsic muscles attached to the spine, with over one million possible pulls. Some of these muscles are intimately attached to the spine, and some

more remotely removed, but, he states, that "surrounding every vertebra there is a balanced muscular function."

It is evident, therefore, that any localized imbalance of these muscles can change the position of the vertebrae—changes which may reach the point of causing pain. Likewise, pain in some portion of the back causing a certain amount of localized spasm in the muscles may cause the patient to assume a position of ease in order to relieve the pain. The faulty position soon causes imbalance of muscle pull in other portions of the spine so that a vicious circle is established which prolongs the disability. Again, complete immobilization of the spine in a plaster cast or a back brace may so limit muscle movement, that contraction of muscle groups occurs—contractions which are extremely painful when subsequent movement is attempted. Frequently this immobilization is in a faulty position with overstretching and thinning of certain other groups of muscles, resulting in weakness. Therefore, the prolonged immobilization treatment adopted for so many back conditions, functional, disease or injury, is often more responsible for the prolonged disability than is the original condition.

Whereas, in sprains about the shoulder, knee or ankle joint, or in case of fractures in or adjacent to these joints, surgeons seem to have a very clear conception of the pathological anatomy and the importance of adapting treatment to preserve function in these joints; yet in injuries to the spine the joint problem is lost sight of too often. In the twenty-four movable vertebrae there are at least forty-eight joints and twenty-four rudimentary joints any of which may sustain direct trauma to their joint surfaces, their synovial sheaths or ligaments or may sustain the traumatizing influence of prolonged immobilization similar to other joints. For example, in a compression fracture of the spine, one may see long after the fracture is healed a permanent disability due to prolonged immobilization of these joints and soft parts in a plaster cast or back brace, a disability due to stiffness and weakness from treatment rather than from the original injury.

Finally, the intramuscular fascia and the aponeurosis covering the back muscles and, in the low back, extending down over the gluteal regions and over the ilia where it becomes attached to and is continuous with the fascia lata, is recognized today as playing a very important part in low back pain. Many of the structural changes in the lumbar region, especially lumbar lordosis, may be attributed to contractions of the iliotibial band and of the tensor fascia lata, ac-

cording to Ober. Either heridity, disease or injury may be responsible for this condition.

When we consider the two primary centers and the five secondary centers from which each component vertebra develops, and the complete failure of some of these centers, or the failure of one part to fuse with its fellow, a clearer conception is obtained of the numerous congenital anomalies that can exist in the spine. These structural changes may become exceedingly confusing when endeavoring to interpret certain roentgenological findings in terms of trauma or even disease.

Among the structural conditions now receiving the greatest prominence are the derangements of the nucleus pulposus. This semi-liquid nucleus encased near the center of the intervertebral disc by the surrounding annulus fibrosus and covered over at the top and bottom by the thin cartilaginous coverings of the adjacent vertebrae —the top and bottom of the intervertebral disc spread like a drum-head over the annulus—is subject to all kinds of changes. Rupture or protrusion of this intervertebral cushion is said to be possible in any direction. When it ruptures posteriorly it *may* give pressure on the cord or spinal roots, thus causing definite back pain with definite referred signs and symptoms in one or both extremities. Schmorl, who is chiefly responsible for our present day knowledge of the nucleus, stated that such herniations were found in 15 per cent of the 7,000 consecutive spines examined by him at routine autopsies. He did not say that all these protrusions were sufficient to give symptoms.

Ormond Beadle, in his valuable contribution, depicts to the profession this monumental work of Schmorl of Dresden, who is chiefly responsible for our modern conception of the intervertebral disc. Beadle states: "The spine is perhaps more than any other part exposed to the daily wear and tear of functional activity and owing to the peculiar conditions this functional trauma, never in abeyance, can continue to work the most far-reaching damage to its structure without causing any noticeable disability. It is for this reason that diseases of the spine often seem so inexplicable; that the examination of large numbers of supposedly healthy spines teaches this point of view as its chief lesson. In what follows it will be the central thought." This author then describes hundreds of spines with all manner of degenerative and proliferative changes in patients with supposedly healthy spines. Large numbers of these had protrusions into the neurocanal, and yet these patients evidently had carried on active

lives with supposedly healthy spines for many years. From a study of Schmorl's work, it is evident that he never intended to give the impression that these conditions were due to one definite trauma or that they immediately follow definite trauma. He referred to "functional trauma" or the wear and tear on the spine the result of normal daily activity. In contradistinction to this, Love states that in 32 per cent of 100 cases immediate trauma was given as the cause. It would be interesting to know what percentage of these 32 per cent were compensation cases. Whereas prior to six years ago this diagnosis was seldom if ever heard, today "rupture or herniation or protrusion of the nucleus pulposus" has almost replaced the old diagnostic terms of "sacro-iliac sprain or slipping" or "lumbosacral sprain."

The latter two conditions, formerly treated by belts and back braces, were rapidly being attacked by spinal fusions when this new diagnostic entity came into the field. In the last four years reports of series of 500, 300, 100, 50, 25 or less, of laminectomies, with or without spinal fusion, for nucleus pulposus herniations or protrusions, are found in the literature. One wonders how the human race tolerated its low back pains and sciaticas prior to this marvelous operation. Unfortunately, the majority of the authors ascribe the condition as due to trauma. Many mean by this term the oft repeated minor traumas of fair wear and tear. But the legal profession abetted by too many physicians and surgeons are interpreting all manner of roentgenological defects in the spine as nucleus pulposus derangements.

The final diagnosis usually depends upon lipiodol injection into the lower spine. Air injections are being advocated but most authorities agree that the information is not as conclusive. One wonders if this iodized oil injection—and a great number of patients are now being subjected to it—is justified except in extreme cases and whether it is altogether devoid of danger. Further reports may yet disprove the harmless nature of this procedure. Furthermore, the few years since these operations started is too short a time to evaluate the end results. Since the human race got along so many centuries without this operation, and since we now have a sufficient collection of cases for the purpose of an adequate study of end results, I personally believe that it behooves the average surgeon to await the final decision of whether this is a passing style or a permanent fixture in surgery. Let us cease firing for two to five years and evaluate results.

Those cases giving the definite signs and symptoms of a cord lesion simulating a cord tumor still must be operated upon just as

they have been in the past. It is impossible to believe that the number of such positive cases has suddenly increased to the point of warranting such widespread laminectomies. It seems a justifiable conclusion to believe that many of these low back pains and sciaticas would yield to less drastic treatment just as they have in the past. Love states: "It is as antiquated to make a diagnosis of sciatica today as to diagnose headache." Nevertheless, I dare say there is more than one surgeon in this audience who, like myself, has had more than one attack of sciatica, who still enjoys and plays a fairly good game of golf. Intractable sciatica not yielding to adequate prolonged simpler treatment may well be due to a nucleus herniation or a cord tumor and may require more drastic treatment. There will always be inexplicable attacks of low back pain and sciatica just as there are unexplainable headaches. Certainly no one would advocate subjecting every headache to a ventriculogram or encephalogram or an exploratory decompression because of a possible brain tumor.

The author is convinced that in a great many roentgenological examinations, depressions in the intervertebral surfaces of vertebral bodies and other intervertebral disc anomalies suggesting derangement of the nucleus pulposus can be demonstrated. Many of these are found coincidentally in patients without the least sign or symptom of back pathology. Such anomalies in patients with low back pain without exceedingly definite neurological signs do not warrant the injection of lipiodol to prove or disprove the presence of a ruptured nucleus pulposus. He is convinced that certain great authorities who have concentrated on this subject definitely have proved the presence of this pathological condition as the cause of the back symptoms and have relieved it by operative procedure. However, the majority of conservative authorities agree that a fairly small percentage of the cases are sufficiently serious to warrant operative procedure. He is convinced that the men who have done the most work on this problem never intended that minor derangements should be an excuse for operation; neither did they intend for the nucleus pulposus to become a medicolegal football. Alleged injuries to the nucleus pulposus, with subsequent permanent disability, bid fair to become more popular than the old "railroad spine," once the favorite with personal injury lawyers and expert witnesses. Therefore, when one is dealing with an injury of the back, with medicolegal or compensation possibilities, he must think twice before injecting lipiodol. The presence of this foreign material at the base of the

spine, demonstrable by *x*-ray, may furnish the claim for the alleged continued back pain, a claim most difficult to refute.

*Finally, all congenital and hereditary conditions responsible for back pain are not inherent in the spine itself.*

The asthenic individuals are the best examples of a hereditary group, prone to have back ache. We are all familiar with this group, referred to by the older clinicians as the Stiller type—the tall, thin patient with a long trunk, flat chest, an acute rather than an oblique epigastric angle and the sunken upper and protruding lower abdomen. None of the previous descriptions of this individual mention the *flat back*, the complete loss of the normal lumbar curve which, occasionally in the young, but almost always in older individuals, is just as characteristic as the ever present acute epigastric angle. Even before the physical examination is made, one can predict that the liver is palpable, that the kidneys are movable and often floating and can verify his suspicion of a dropped stomach by *x*-ray. However, such an *x*-ray should be condemned, because when made and the patient is told that he or she has a "fallen stomach" it only serves to aggravate the symptoms and the mental depression.

In outlining the acute intercostal angle with the finger nail or a pencil, the typical tache cerebrale, or red streak, is left on the skin, thus suggesting vasamotor changes as characteristic of such patients.

We are all likewise familiar with the tachycardia and the heart complaints of many of these individuals; the dyspeptic complaints of others and other innumerable fears of grave intra-abdominal disease, especially malignancy. My favorite question put either to the patient or to a close relative if one is present is: "Is this patient one of the worriers of the world?" Invariably the relative answers, "yes," although the patient usually denies it. Even in taking the history, this element of worry is quite apparent.

In considering the diagnosis of low back pain, and especially in the differential diagnosis from alleged injury, the author wishes to stress his four characteristic cardinal conditions inherent in these patients, namely, (1) the faulty posture; (2) the flat back; (3) the spastic colon, palpable in the majority, but suggested always by the history of flatulence, constipation or intermittent diarrhea, especially after some emotional upset; and (4) the great tendency to worry about and exaggerate their symptoms.

The above cardiac, dyspeptic and neurotic tendencies of these patients are common knowledge, but too little attention has been

paid to the asthenic group with back complaints, especially low back pain, often accompanied with sciatica.

Just recently this group is being approached from another angle. Read the recent descriptions in the literature of the disease called "fibrocytis," and see how many of these authors group the typical neurasthenic type, the effort syndrome type, the easily fatigued individual, the highly tensed spastic gut executive or society lady, as the ones most prone to fibrocytis. Not all of these are of the asthenic build but the symptoms so characteristic of the asthenic are found in the majority. Space will not permit further consideration of fibrocytis, but it is definitely a disease entity that must be considered in the differential diagnosis of many alleged minor injuries to the back with persistent symptoms.

*Flat Back.* A patient from another city who had fallen at work and ascribed his low back pain to the injury was referred to me after several weeks. Absolutely no other cause but the flat back and the asthenic characteristics could be found to explain his condition. Physical therapy and exercises to redevelop the lumbar curve were prescribed. He was making fairly good progress, when a relative persuaded him to go to a clinic. There the orthopedist told him that they did not take any stock in Mock's flat back theory. No diagnosis was made but he was fitted with a back brace. He returned home but the condition grew worse, especially as his compensation had been cut off. He became discouraged with the back brace. After a lapse of three months he returned to me. A thorough examination, *x*-rays and all laboratory tests were repeated with negative results. Two hours were then spent in explaining to this patient the hereditary factors in his physical and emotional make up. Fortunately, he recalled that his father had exactly the same build and was troubled with backache. I persuaded him that any effects of the minor injury had long disappeared and that he could carry out his exercises for re-establishing a better lumbar curve and could regain his emotional balance just as well while working as while loafing. The company agreed to pay him compensation to this date. He returned to work, and for over a year there has been no complaint from his back. You may say that this was a "compensation neurosis." True, these individuals are prone to develop neuroses and the majority of their complaints are on a nervous basis. In prescribing treatment for such individuals and especially inadequate physical therapy and back braces, one is liable to doom them to a permanent disability. In many of them, however, the low back pain and the sciatica is so acute that

there must be an etiological factor other than neurosis. In my opinion, that etiological factor is the *flat back* with its accompanying abnormal ligamentous pulls and strains, the muscular imbalances that supervene, the faulty postures assumed to ease the pain, and finally, the contracted aponeuroses and tensor fascia lata which, in time, may become a persistent factor in the chronicity of the condition. It is worthy of emphasis that the individual with flat back and with the other three cardinal characteristics mentioned above has a chronic weak back, prone to pain and discomfort on the slightest unusual strain or stress. The tendency to worry over slight symptoms aggravates the condition into a terrible calamity. The fair wear and tear of our daily existence develops certain fatiguing influences which manifest themselves in some way in the majority of us. It is safe to say that 80 per cent of the asthenic individuals who develop low back pain are in the age group between thirty and forty years. This has been a common observation on the part of myself and associates. It is my opinion that the above mentioned fatiguing influences reach their height in these individuals in this decade. Comparable to this are the neurocirculatory changes and the condition called "effort syndrome," most frequently seen between twenty and thirty years of age.

Before leaving disease conditions which may cause low back pain and which may simulate or be coincidental with injury, reference must be made again to persistent fibrocytic nodes as well as to painful subfascial lipomas. It has been pointed out by certain authorities that the asthenic type is more prone to low grade infection which probably accounts for the greater prevalence of spondylitis in this group. Likewise, many of the investigators of fibrocytis have stressed the prevalence of the condition in the asthenic individual or in those having a fatigue background. These two facts are enlightening from the etiological standpoint. Certainly the pathological studies of certain of these fibrocytic nodes which have been removed strongly suggest an infectious nature.

Painful subfascial lipomas, especially in the lumbosacral region, are not at all uncommon and are frequently mistaken for these fibrocytic nodes. We have no reason to believe that these lipomas are the result of trauma. In case of back injury with medicolegal possibilities, one must not be too quick to jump to the conclusion that persistent nodes, whether fibrocytic or lipomatous, are the cause of the alleged pain or are related in any way to the injury, and therefore warrant operative removal to cure an alleged injury. Like lipiodol injections,

the presence of an operative scar is visible proof to the laity of some preexisting serious condition, and the patient's alleged continued pain and disability are, therefore, very difficult to refute.

*X-ray.* The *x*-ray is invaluable in the diagnosis of back injuries and yet many *diagnostic pitfalls* exist if too much dependence is placed upon the presence or absence of *x*-ray findings. It is too often neglected in cases resulting from rather minor accidents, or is not resorted to until weeks or months later. The late *x*-ray may show osteoarthritic changes or even an old compression fracture, and because of the failure to take an immediate *x*-ray, one is unable to say definitely that this or that condition was pre-existent and without relationship to the alleged injury. The following roentgenological diagnostic pitfalls are extremely common:

I. The chief pitfall is the tendency to accept as final the statement that the *x*-ray of the spine is negative. We seem to forget that the *x*-ray will not show the ligaments, muscles, aponeuroses and other soft parts, and, therefore, when bone pathology is absent, we overlook the possibility inherent in the soft parts for both injury and disease. Furthermore, infectious conditions of the spine or early metastasis in the vertebrae often do not show in the first or even in the second *x*-ray.

II. The next commonest pitfall is to accept as final and conclusive evidence of the cause of the low back pain the *x*-ray findings of arthritis or of a nucleus pulposus derangement or of an acute angulation between the fifth lumbar and the sacrum, or other acquired or congenital anomalies. I have at least half a dozen examples of slight to marked spondylolisthesis, giving no signs or symptoms of low back pain and found inadvertently while examining for other conditions.

## CASE REPORTS

CASE I. L. M., sixty years of age, ran for a moving train. A red-cap seeking to intercept him was responsible for his fall on the platform. He sued the railroad for $50,000. He was taken to one of our best hospitals, and an excellent surgeon diagnosed, following an *x*-ray, compression fracture of the first lumbar vertebra. I examined this patient with the attending surgeon four months later. The patient was confined to bed and was wearing a back brace. There were very acute signs of low back pain. The prostate was enlarged, but not abnormally so for a man of sixty. The remainder of the examination was negative. Examination of the original *x*-rays, which were the only ones that had been made, showed slight compression of the three lower dorsal and the two upper lumbar vertebrae with a more marked

narrowing of the first lumbar. The intervertebral spaces were narrowed and there was marked evidence of calcification of the anterior ligament and spur formations typical of an osteoarthritis. The attending surgeon insisted that the changes in the first lumbar were due to a compression fracture. The roentgenologist firmly believed that the narrowing of this, as well as of the other vertebrae, was more indicative of an osteoarthritis. This was likewise my opinion. Re-*x*-raying of the spine was suggested but was not done. The patient, wearing his back brace, left the hospital a few days later. Three months later the patient committed suicide. The autopsy revealed carcinoma of the prostate with metastasis to the spine. Additional later *x*-rays would have revealed the condition. I am told that the suit has been dropped.

CASE II. M. C., a young lady, twenty-four years old, was struck by a bus. Her injuries were minor and she was confined to the hospital only two days. The *x*-ray was considered negative. Later I examined this patient with an orthopedic surgeon who claimed she had a herniation of the nucleus pulposus. Her symptoms were exaggerated but practically no signs were present. His diagnosis was based upon a concavity in the superior surface of the body of the fourth lumbar vertebra. I showed him the *x*-ray of a nurse which showed an identical concavity, and yet there were absolutely no back or extremity complaints. He insisted that in spite of the absence of complaints this nurse had a herniation and that some trauma had occurred to account for it. This surgeon has become one of the outstanding exponents of trauma as the cause of all nucleus pulposus derangements and is a frequent witness to this effect. For every such case of alleged herniation due to trauma, I can show a similar *x*-ray finding of a concavity in a vertebra, even in young adults who have no sign or symptom of disability from the condition.

III. Why any surgeon or roentgenologist in this day of enlightenment should be content with only an anteroposterior view of the spine is inexplicable. Both lateral and oblique views are far more important for diagnosis.

CASE III. A. R., injured in an automobile accident in Michigan, was taken to a hospital and an *x*-ray of his back was made. It was reported negative for fracture. A contused back was diagnosed. Treatment consisted of rest in bed for two weeks. He returned to his home in Chicago and, because of continued pain, received osteopathic treatment for two weeks. He then secured a lawyer and started suit. The lawyer referred him to a doctor who secured *x*-rays of his back and, in the lateral view, discovered a compression fracture of the first lumbar vertebra. At the end of ten weeks the insurance company involved referred the patient to me, with the consent of his lawyer, for examination. I found the evidence of the old compression fracture in the first lumbar vertebra. Anxious to compare this with the original film made directly after the injury, I wrote to the doctor

in Michigan for his films. They were sent, and to my surprise, included only an anteroposterior view, which failed to show the fracture. Failure to take a lateral view was responsible for this very good physician's failure to diagnose and adequately treat a compression fracture of the spine. This is a very common mistake.

IV. It is far wiser to *x*-ray the entire spine in the presence of an alleged injury than to fail to *x*-ray a sufficient expanse of the regional spine necessary for the diagnosis of a recent or old condition.

CASE IV. W. B., a locomotive fireman, jumped from his engine when the boiler burst. He suffered first degree burns about the arms and legs. The engineer was knocked to the floor of the cab, sustaining a fractured leg and severe burns. The fireman pulled the engineer out of the cab, and later was able to walk to the ambulance that brought both of them to the hospital. The engineer was hospitalized for weeks and finally secured an excellent recovery without permanent disability. He settled his claim for a nominal sum. The fireman's burns were rather insignificant. The second day he complained of low back pain, indicating the site of pain as opposite the fourth lumbar vertebra. An *x*-ray, anterosuperior, lateral and oblique, was made of the lumbar spine. It was negative for any bony pathology other than a slight arthrosis, due to fair wear and tear. He was discharged at the end of two weeks. He refused to go to work because of an alleged low back pain. His variable points of pain, his exaggerated walk and the marked exaggeration of symptoms caused me to believe that this man was suffering from a "compensation neurosis." At the end of six months he secured a lawyer and filed suit for $50,000. With the lawyer's consent he was returned to me for a check-up examination. I learned that he had been to two other doctors, chosen by his attorney, both of whom had likewise *x*-rayed only the lumbar spine. One of these called the arthritic condition in the fourth lumbar vertebra, a fracture, while the other said that it was due to a deranged nucleus pulposus. My physical examination revealed a marked increase in the exaggerated signs and symptoms as compared with my last examination, four months previously. *He was now wearing a back brace.* At this time I took an *x*-ray of the *entire spine.* This revealed an old compression fracture of the tenth dorsal vertebra, so definite that no one could overlook it or ascribe it to any other condition. It had all the earmarks of being a very old compression fracture, but neither the roentgenologist nor I could swear that it was older than six months. I am positive this was an old pre-existent fracture. The patient gave a history of an old back injury, but for some unknown reason was evidently confused as to its location. My failure to have made an *x*-ray covering a sufficient expanse of the vertebrae when he first came under my care was extremely embarrassing, and my chagrin was not assuaged by the fact that two other surgeons employed by the lawyer had made the same mistake.

v. Given a sudden low back pain, whether ascribed to trauma or otherwise, and the immediate *x*-ray is negative, it is rather common practice to diagnose the condition as sacroiliac sprain or to call it lumbago or sciatica. Frequently, a definite diagnosis can not be made. But in the presence of persistent back pain, it is simply courting trouble to rest on our oars with the original diagnosis, to be content to have the patient wear a sacroiliac belt, and neglect further observation and especially further *x*-rays. Here is an exceedingly important *x*-ray rule: *With the original x-ray negative but with the back signs and symptoms persisting, without a conclusive demonstrable cause, x-ray that spine at frequent intervals.* Too often the compression fracture will not show in the first film, but with movement and weight-bearing, the compression gradually develops, and the later film reveals the true condition. In the case of persistent trouble, the second, third or even the fourth film may be the only means of diagnosing the metastatic tumor which all along has been the cause of the back pain, rather than some minor injury which was coincidental.

CASE V. Doctor T., age fifty-two, had his chair collapse while attending a medical meeting. As he fell to the floor the back of the chair struck him in the middorsal region. A colleague examined the back and advised immediate hospitalization. The next morning the spine was *x*-rayed following which the doctor patient was informed that there was no evidence of fracture or dislocation in any of the vertebrae and that after a few days' rest he would be all right again. No further examination was made and neither were additional *x*-ray films taken yet the pain in the back persisted. He required morphine for four or five days to relieve the pain. At the end of the week the patient called an excellent internist who examined him thoroughly and also examined the *x*-rays. He pointed out an osteoporotic condition of the bones which had been noted previously by the roentgenologist but he could see no evidence of fracture. The doctor patient began to sense that he was considered a "neuro," and thought that possibly he was. He left the hospital at the end of fifteen days, and the following day went to his office in a taxicab. After a few hours in his office he collapsed. There was excruciating pain and marked dyspnea. He was taken home and the internist again called. The latter stated that his examination revealed a spasm in the muscles of the back and the chest muscles on the least effort at deep breathing. The internist again visited the hospital and examined the original *x*-rays but again could find no sign of injury to the vertebrae. A month later the internist asked the author to see this doctor, stating that while he was a marked "neuro" yet he might have some injury to the back. Examination at this timed showed a definite knuckle

deformity over the eighth dorsal vertebra. He was taken to the hospital and *x*-rayed. Examination of these films showed in both views a very marked compression fracture of the eighth dorsal vertebra. The original *x*-rays were secured and examined for comparison and all who viewed them agreed that they failed to show this fracture.

CASE VI. Mrs. B., age forty, married, sustained a fall of little consequence in her home in March, 1929. Approximately two weeks later she complained of pain in her lower back. A good surgeon, a close friend of the family, was consulted. An *x*-ray examination was made which was negative for bone pathology. Because of the history of falling and because the pain and tenderness were located near the left sacroiliac region, a diagnosis of sacroiliac sprain was made, and the patient was treated with heat, massage and strapping. The pain persisted and subsequently a sacroiliac belt was prescribed and worn. After five months of treatment without relief, the surgeon made another *x*-ray examination. This film showed a marked metastatic carcinoma of the left ilium near the sacroiliac joint. The author visited this patient with the surgeon. Our examination at this time revealed a very small lump in the breast, most probably the source of the primary growth. It was the author's sad duty to explain to the husband the incurable condition, and to endeavor to make him understand why it showed in the second *x*-ray, while not visible in the first. Of course, the condition could have been discovered earlier by the rule laid down above.

VI. Failure to take an *x*-ray following an alleged injury, chiefly because the patient is feeling better when seen by the doctor, or the physical findings do not seem to warrant an *x*-ray or even to save expense for the patient or some insurance company or corporation, is one of the commonest pitfalls in the diagnosis of low back pain.

CASE VII. Mr. B., age sixty, an engineer, fell from his engine and struck his back across a rail. He was carried to his home and a doctor called. The examination was negative but the doctor suggested that if the patient was still in pain the next morning he would take him to the hospital for an *x*-ray. However, the patient was better and no *x*-ray was taken then or at a later date. After a week the patient got out of bed and limped around the house and yard but always complained of pain in his spine, especially on arising from the bed or a chair. He was referred to the author for examination after six months, with the statement that the old man was making too much out of his case and was endeavoring to get a pension. Whether an immediate *x*-ray would have shown the condition is problematical, but the roentgenological examination made at this time revealed a slight fracture of the first lumbar vertebra, and a definite compression of the third.

### DIFFERENTIAL DIAGNOSIS

When the trauma is of such magnitude as to be quite obvious, and especially if the *x*-ray unqualifiedly proves the presence of injury, the problem of diagnosis is simplified. Even here, however, a thorough search for remote, less obvious injuries is essential. Failure to recognize this may doom the individual to a permanent disability in another part of the body, due to neglect of treatment. Likewise, a search must be made for the coincidental disease which may influence the management and prognosis of the case.

In the case of sudden low back pain, in which the question of injury is often problematical or an after-thought, the surgeon must become a veritable detective, for many are the physical, mental and compensation problems that coexist and may be responsible. Every logical clew must be sought and thoroughly investigated before the guilty factor or factors of low back pain can be finally indicated and honestly attacked. Thus, in searching for the cause of low back pain, *do not be content with x-ray and physical examination of the back alone,* whether the patient presents himself as an injury case or as one who has developed the condition without history of injury. The wise surgeon will search the entire body, and will utilize all necessary laboratory tests, ruling out possible conditions which may be of equal or greater etiological importance or which may influence the course of treatment and the patient's ultimate recovery.

While pain in the right lower quadrant suggests appendicitis, or pain in the right upper quadrant suggests gallstones, yet pain in the back must suggest a multitude of conditions. It may be the first symptom of a general infection, for example, the "flu" or smallpox; or the first symptom of a disease of the cerebrospinal system, as poliomyelitis, or the first evidence of a *genitourinary affliction,* for example, a stone in the kidney.

*Gynecological conditions,* especially fibroids and ovarian cysts, often give the first evidence of their presence by backache. For weeks this may be the only manifestation of an acute pelvic infection. Fortunately, the displaced uterus, when operated upon because of low back pain, has failed so often to relieve the situation that it is seldom attacked today as a causative agent. Uterine suspension is going out of style.

*Primary carcinomas anywhere,* but especially in the breast or prostate, very frequently attack the spine with their metastatic growths. The same is true of the obscure, often very difficult to

discover, bronchiogenic carcinoma. Hypernephromas may likewise give their first evidence by their metastatic appearance in bone. These secondary growths may be so infinitesimal that for weeks and even months they fail to give either physical findings or *x*-ray manifestations of their presence. We have already considered the diagnostic pitfall of failure to re-*x*-ray the back in the case of Mrs. M., with the small primary growth in her breast. Failure to make a complete physical examination including the rectal examination, combined with the later follow-up *x*-ray examination was responsible for one excellent physician failing to make a diagnosis of metastatic carcinoma of the prostate in the case of alleged injury, as exemplified by the following case report:

CASE VIII. Mr. T., sixty-three years old, a teamster, slipped on the ice while working for the village of R. In falling he struck a wagon wheel. He completed his day's work but the next day had pain in his back, and, therefore, went to the village physician. An *x*-ray examination was made but was negative for bone pathology. His back was strapped. The pain persisted but he was able to work on and off for a few weeks and then was forced to quit. The original *x*-ray showed marked osteoarthritis present, and the village physician believed that the original injury was not sufficiently serious to warrant the village assuming responsibility for this pre-existent condition. Furthermore, he felt that the old man was unduly exaggerating his complaints of pain. At the end of two months following this alleged accident he was referred to me for examination. The patient was definitely suffering back pain. There was marked limitation of motion, probably due to osteoarthritis. The examination of the back was negative, except for a definite constant point of tenderness in the region of the fourth lumbar vertebra. The rectal examination revealed an enlarged prostate that was undoubtedly malignant. An *x*-ray examination showed a destructive process in the body of the fourth lumbar vertebra, which was diagnosed by Dr. Hollis Potter as a metastatic carcinoma. The source of this growth was undoubtedly the prostate.

*Bone sarcomas* may attack the lower spine or the pelvis primarily or sarcoma in other regions of the body may form metastasis to the spine. Any one of these may give symptoms of low back pain for weeks before the sarcomatous lesion is demonstrable by *x*-ray.

CASE IX. A close friend of mine, a noted orthopedic surgeon, recently treated the son of a doctor for a slight injury to his spine. The original *x*-rays were negative and the cause of the condition obscure. The spasm in the muscles, the contraction of the fascia lata and the list of the spine, with the acute lumbar lordosis, caused them to contemplate operative pro-

cedures. Fortunately, before anything was done, another *x*-ray was made which revealed an osteogenic sarcoma of the left ilium.

Grave responsibility rests upon the surgeon presented with such a case, for often he must meet the medicolegal problem of whether an alleged injury is responsible for the sarcoma or even other forms of malignancy. (See previous paper on "Trauma and Malignancy" by Mock and Ellis, *J. A. M. A.*, January 23, 1926.)

*Gastrointestinal* conditions, for example, gastric or duodenal ulcers or the subacute retrocecal appendix, as well as gallstones, may be the source of the low back pain. Frequently, on jumping out of bed or leaning over to lace the shoe, or after lifting some object in the home, the low back pain suddenly develops and the patient ascribes it to the trivial accident. When the acute low back pain from these intra-abdominal conditions starts following lifting or other strain, while the patient is at work, it is not only important but often difficult to differentiate between alleged injury and low back pain from disease.

Case x. Mr. N., a railroad official, was riding on his own railroad when a slight wreck occurred. He sustained a severe jolting and jerking. That night he developed a severe pain in the region of his eight dorsal vertebra. The pain persisted and on a few occasions caused vomiting. The *x*-ray of the spine was negative. At the end of a week he had a severe gallstone colic and the pain in the back grew much worse. Visualization of the gallbladder revealed gallstones. In the interval between attacks, the back pain persisted. At the end of a month I operated upon this man for gallstones, with complete relief of pain in the back. We have all observed acute gallbladder attacks developing shortly after some similar accident. What the relationship is, is difficult to explain, but obviously the true cause is the presence of the gallstones, rather than the accident. However, all the expenses of this patient's surgical ordeal were borne by the railroad, because of some problematical connection between the accident and the gallbladder attacks.

The above conditions, as well as many other acquired and hereditary abnormalities that the body is heir to may refer pain to the back and especially the low back. Hardly a day passes that most of us do not sustain sudden jolts, twists or strains and even falls. If a low back pain develops coincidentally with such minor accidents, it is only human nature to ascribe the condition to the most obvious factor, viz., the accident.

Conversely, disease and even traumatic lesions in the spine may refer the major symptoms to remote parts of the body, while the

local symptom of back pain is negligible. In such instances, the true lesion in the spine may be easily overlooked. The best examples of these are: (1) The gastric crises of tabes or the referred pain and paresis in an extremity, the result of a cord tumor. (Pernicious anemia was found as the cause in one alleged back trauma.) (2) Osteoarthritis of the dorsal vertebrae may cause referred pain around the chest simulating angina. (3) The osteoarthritis of the lumbar vertebrae, with impingement on the nerve roots and referred pain down the sciatic nerve or at least into the gluteal region, while the back pain is negligible, is a typical example.

This reference of pain and other symptoms to parts of the body removed from the spine is occasionally observed in major injuries to the spine, thus giving rise to some of our most confusing diagnostic problems.

CASE XI. An old gentleman, almost eighty years old, accompanied his two daughters on an automobile trip to a nearby city. He rode in the back seat. While driving rather rapidly the daughter struck a bump which threw the old gentleman to the top of the car and then to the floor. He climbed back on the seat and said he was not hurt. However, by the time they reached their destination he was suffering severe pain in his bladder and had a complete suppression of urine. A genitourinary specialist, a close friend of the family they were visiting, was consulted. This specialist diagnosed hypertrophied prostate with acute retention, and immediately did a cystostomy as the first stage in a proposed prostatectomy. When the time came for the second stage operation, the old gentleman insisted on returning to Oklahoma City, his home town, for the operation. Here the genitourinary specialist consulted believed that the prostate was not sufficiently enlarged to account for the trouble. He mentioned the case at the doctors' luncheon table and incidentally referred to the above bump and fall. Our old friend, Sam Cunningham, suggested an *x*-ray of the spine before removing the prostate. This was done, and a compression fracture of the first lumbar vertebra was discovered. This was treated and the old gentleman made a good recovery and kept his prostate until his death, three years later.

*Radiculitis*, or inflammation of the spinal nerve roots, is frequently ascribed to trauma. The pain is often referred to the extremities. How one can truly ascribe the condition in a given case to trauma rather than to irritation from small osteoarthritic deposits in the vertebral margins or without first ruling out cerebrospinal syphilis or some of the causes of peripheral neuritis, such as diabetes, alcoholism or lead poisoning, is extremely difficult to conceive and

yet radiculitis from trauma is not an uncommon medicolegal claim. Injury is likewise frequently held responsible for other forms of neuritis, as well as for myositis, myofacitis and other conditions of the soft tissues which may be accompanied with low back pain.

### DISABILITIES DUE TO FAULTY TREATMENT

It is extremely important to diagnose the back pathology or the condition elsewhere causing low back pain before instituting any drastic or prolonged course of treatment. Faulty diagnosis too often leads to faulty treatment with the danger of permanent damage to the patient or an extremely embarrassing position for the surgeon. Finally, the treatment adopted may often result in pathological changes which are responsible for the continued low back pain long after the original condition is healed.

We are all familiar with the painful inflammatory reaction which usually follows the forcible breaking up of a soft tissue ankylosis in the shoulder joint, elbow or knee joint, and the danger of causing more pronounced stiffness and even permanent ankylosis from such a procedure. Yet many an injured or diseased back, the result of the acute condition or of the prolonged treatment, has a similar soft tissue ankylosis of some of its joints. Forceful osteopathic treatments to such a spine often results in prolonged symptoms of low back pain and even permanent disability. Manipulative surgery, used more and more in back conditions by surgeons and physical therapists, may, and do, result in prolongation of back pain and permanent disabilities, a danger which can be prevented only by a clear understanding of the existing pathology.

In the treatment of compression fractures of the spine, the forceful reduction of the compressed vertebra, under a general anesthetic, is strongly advocated by many. When the patient is asleep and cannot resist, it is difficult for a surgeon to gauge the amount of force he is exerting in such manipulations. Jacks, slings and other mechanical means of immediately reducing the compression have been devised. The amount of force exerted through these various mechanisms is even more difficult to gauge. It is, therefore, conceivable that the continued painful back persisting for months following the healing of such fracture may be due to torn ligaments and other ankylosing influences in and about the given spinal joints.

The older method of treating compression fractures, viz., rest in bed with or without hyperextension for several weeks without any effort made to maintain soft tissue tone and joint function, and then

placing the patient in a plaster cast or a back brace which he wore for several months to a year often resulted in even greater prolongation of symptoms and frequently permanent disability. Just as in other joints of the body, the prolonged immobilization resulted in a certain amount of soft tissue ankylosis, with atrophy of disuse and weakness of the back muscles and contracture of the aponeuroses. Undue prolongation of low back pain with eventual recovery was the rule for the young and middle aged, while the old were frequently doomed to permanent disability. It was because of the above results that some surgeons began advocating a spinal fusion for compression fractures, stating that they obtained quicker results and fewer cases with permanent disability. Their premise was wrong for there was no rime or reason in the old prolonged treatment of compression fractures.

In my opinion, neither forceful reduction of the compression fracture under anesthesia, nor the fusion of the spine in the presence of such fractures, nor the prolonged immobilization in a back brace are seldom, if ever, indicated.

The author's treatment of compression fractures gradually evolved in the last ten years since he gave up the use of prolonged immobilization and especially the use of back braces, is based upon anatomical and physiological facts, viz.:

1. The multiple joints about each vertebra.

2. The capsule and adjacent ligaments about these joints, as well as the more distant ligaments of the spine which may be stiffened by prolonged immobilization.

3. The soft tissue changes, the result of atrophy and disuse, which may occur in the muscles and aponeuroses.

4. The need of hyperextension with the resulting muscle and ligamentous pull on the body of the vertebra to overcome the compression. By increasing this hyperextension daily and within the patient's tolerance, the reduction of the fracture can be obtained just as well and with far less danger than by forceful hyperextension under anesthesia, within a period of two weeks.

5. Early mobilization of the joints by allowing hyperextension exercises, and as soon as the hyperextension cast is applied, allowing the patient to walk, usually at the end of three weeks.

6. Maintaining muscle tone and strength and pliable aponeuroses by the daily use of heat and massage, facilitated by turning the patient onto his belly while still maintaining the hyperextension position, and later, after the hyperextension cast is applied, cutting

a large circle in the back of the cast for the purpose of continuing heat and massage.

7. The fractured vertebra is healed at the end of eight to ten weeks, depending upon the physical condition of the individual, and at this time removal of the cast. If the physical therapy and exercises have been carefully and properly performed daily, the patient will not feel the need for a back brace or other support. No patient of mine with a compression fracture has had a back brace within the last ten years.

In the author's opinion, the symptoms of prolonged low back pain, stiffness and weakness in the back, weakness in the lower extremities, and the characteristic short-step limp, are usually due to a faulty line of treatment rather than to the original compression fracture.

*Physical therapy*, unless used intelligently, may be far more responsible for the continued low back pain than is the original disease or injury. Given a trivial injury in a nervous individual who shows a tendency to exaggerate his condition, one can often rub in more disabling conditions in a week than he can rub out in a year. The use of diathermy, quartz and other kinds of lights, mechanical exercisers, vibrators, and similar apparatus, often serves more to impress the patient with the seriousness of the situation rather than to cure him. Common sense and intelligent hand work are the essential factors in physical therapy to the spine. Rarely is machine therapy indicated. The overly enthusiastic, talkative physical therapy technician, suggesting a curvature of the spine here, a spasm in the muscles there, or the presence of painful nodes, is a menace in any back case.

*Operative procedures* on the spine are definitely indicated in certain well defined but limited conditions. A correct diagnosis of these conditions is imperative. Operative procedures in a group of poorly selected patients too often result in prolonged or even permanent disability or is actually worthless and thereby discredits legitimate back surgery.

CASE XII. Dr. Vincent O'Connor, of Chicago, has loaned me a lantern slide, taken one month after the patient had been subjected to a double bone graft operation for a spondylolisthesis. The orthopedist jumped to the conclusion that the severe low back pain was due to the spondylolisthesis, evidently shown in his original *x*-ray. In Dr. O'Connor's film, taken a month later, the metastatic carcinoma, shown in the ilium and lower

spine, furnishes the true clew for the pain. The primary growth was in the prostate.

## CONCLUSIONS

1. Low back pain, the result of major injuries to the spine, is not a difficult diagnostic problem usually.

2. When the low back pain follows a minor injury or the history of injury is obscure or often an after thought, every possible etiological factor must be sought for and weighed before ascribing the condition to trauma.

3. The fair wear and tear of every day life—"functional trauma," congenital and acquired conditions in the spine, hereditary tendencies and constitutional diseases in remote parts of the body may be responsible for the back pain rather than some alleged trauma. The roentgenological findings in spines with these congenital and acquired changes must be studied exceedingly carefully before ascribing such changes to trauma.

4. The too facile explanation of trauma as the cause of the pain or of these congenital and acquired changes may cause one to overlook the true cause, for example, a metastatic tumor or other constitutional factor, with the result that great injustice and even permanent damage may ensue.

5. The clinical and roentgenological pitfalls which exist in the diagnosis of low back pain and in the etiological factor of trauma are illustrated with twelve case reports.

# OUR CHANGING IDEAS CONCERNING PROTRUSION OF INTERVERTEBRAL DISCS

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DURING the last decade there have occurred numerous and drastic changes in our conception of protrusion of intervertebral discs. At this time it does not seem amiss to point out a few of these changing ideas and to consider some questions which are still controversial.

The conception of the pathological nature of this interesting lesion was the first idea to undergo revision. Adson[1] (1925), Stookey[28] (1928), Bucy[5] (1930) and others reported cases of spinal cord compression in which the tissue pressing upon the cord was thought to be neoplastic and to which the term "chondroma" was applied. In 1929, both Schmorl[24] and Andrae[3] published studies on the spinal column, and since then it has become evident that instead of these lesions being neoplastic they are abnormal protrusions of part of the intervertebral disc. In the same year Dandy[11] reported two cases of protruded intervertebral discs and correctly stated that the "tumor" was cartilage detached from the disc.

There is still no complete harmony of opinion concerning the portion of the disc tissue which protrudes, and, therefore, no agreement on a name for the condition. The term, "rupture of the intervertebral disc," was at first used by Mixter and Barr.[22] Later microscopic studies[12] of the disc tissue removed at operation led to the conclusion that posterior protrusions of intervertebral discs which caused symptoms were composed of all parts of the disc including the annulus and the nucleus with its occasional remnants of notochord. Therefore, the term, "protruded intervertebral disc," was considered proper. Others,[26] however, preferred the term, "herniated nucleus pulposus," in preference to "protruded intervertebral disc" because they believed that nerve-root compression practically always was due to a rupture of the annulus fibrosus with an extrusion of the nucleus pulposus through the defect.

Mixter[21] accepted the term, "protruded intervertebral disc," in preference to "extrusion of the nucleus pulposus." In a recent communication Spurling and Grantham[27] maintained that the

annulus fibrosus must be ruptured or torn for symptoms to be produced; if there is no extrusion of the nucleus pulposus, one set of symptoms appears; and if there is an extrusion, another set of symptoms occurs. They, therefore, used the term, "rupture of the intervertebral disc," with or without herniation of the nucleus pulposus.

Saunders and Inman[23] agreed that two types of protrusion occur. In some cases they noted fissuring of the annulus surrounded by "brown degeneration" with herniation of the nucleus, in other cases collapse of the disc with protrusion of the annulus with or without herniation of the nucleus.

The 1934 report of Mixter and Barr[22] served as a starting point for another change in our conception of protruded intervertebral discs. Prior to this article protrusion of the intervertebral disc was considered a rare cause of low back and sciatic pain, but after they focused attention on this lesion its presence has been recognized frequently and operation for its removal carried out commonly. Enthusiasm regarding protrusion of intervertebral discs was accelerated to the point that every patient who complained of backache or sciatic pain was looked on by the neurological surgeon with an acquisitive eye. That every patient with a pain in his back does not have a protruded intervertebral disc has been emphasized by Henderson[16] who reported that during a three-year period orthopedic consultants in the Mayo Clinic saw 10,000 patients who complained of low back or sciatic pain. Of the 10,000 patients only 188 or 1.8 per cent were subjected to operation for removal of protruded intervertebral disc. Since January, 1937, 142 patients complaining of backache and sciatic pain have been referred to me because of possible protruded intervertebral disc yet after neurological studies were made only nineteen (13.4 per cent) were operated upon for removal of protruded intervertebral disc or hypertrophied ligamentum flavum. I believe the rôle of protruded intervertebral discs in the production of low back and sciatic pain is finding its proper place.

Formerly it was the opinion that protrusion of an intervertebral disc was nearly always a result of trauma to the spine. Barr, Hampton and Mixter[4] in 1937 reported that a history of trauma to the lower back was obtained from 80 per cent of patients with proved rupture of an intervertebral disc. In a recent analysis[19] of 500 consecutive cases in which operation was performed it was found that only 58 per cent of the patients gave a history of specific injury to the back. Apparently then, in the presence of suggestive symptoms

and signs, one is justified in suspecting a protruded disc even though no history of trauma to the back can be obtained.

Another point upon which opinion has changed since we first began to recognize the condition concerns the total protein content in the spinal fluid. It formerly was thought that a total protein content of more than 40 mg. per 100 cc. of spinal fluid was always present in patients who had protruded intervertebral disc. Later[2] it was announced that about 25 per cent of the spinal fluids from patients with protruded intervertebral disc had a total protein content of less than 40 mg. In 1939, Love[18] stated that 34 per cent of the specimens of spinal fluid tested from 265 patients with protrusion of intervertebral discs had less than 40 mg. of total protein per 100 cc. of spinal fluid. Still later Love and Walsh[19] reported a series of 500 cases in which 40 per cent of the patients had less than 40 mg. of total protein per 100 cc. of spinal fluid in the specimens submitted for analysis. They believed that the low values from the total protein in the more recent series were due to changed spinal puncture technic. Previously, the puncture had been done as low as possible whereas more recently the puncture was between the first and second or the second and third lumbar vertebras, so that an air spinogram could be done at the same time. Therefore, the spinal fluid obtained in the more recent cases was at a greater distance from the protruded disc which was usually located at the fourth or fifth lumbar interspace. The idea that the total protein content of the spinal fluid was higher near the lesion than at some distance from the lesion led to the practice of keeping the first 3 cc. of fluid separate from the remaining 7 cc. when a low lumbar puncture was done. However, in a study of more than 200 consecutive cases in which lumbar puncture was performed, Eaton[13] found that a comparison of the total protein content of the first 3 cc. of cerebrospinal fluid with that of the remaining 7 cc. of cerebrospinal fluid removed at lumbar puncture was of little or no value in detecting or excluding organic lesions such as protruded intervertebral disc in the region of the cauda equina.

The last few years have brought changes in our ideas of the roentgenological methods employed in diagnosing protrusion of intervertebral discs. To quote from a 1937 article,[20] "Unless a definite level of motor or sensory loss is determined on neurological examination, subarachnoid injections of radiopaque oil for fluoroscopic and roentgenologic examination of the spinal canal is essential to establish a diagnosis of an intraspinal lesion. . . . If such a study

is negative for an intraspinal lesion, laminectomy for the removal of a protruded intervertebral disk should not be considered, for, in experienced hands, the smallest of defects can be diagnosed and localized by this technic." Injection of iodized oil still remains the most popular and most certain method of definitely establishing the diagnosis of protrusion of an intervertebral disc. Camp[6] stated that in a series of 210 cases in which the patients were subjected to operation, oil studies revealed the presence or absence of an intervertebral disc with an accuracy of 92.3 per cent. A figure closely approximating this was given by Hampton[15] when he stated that a positive diagnosis of a posterior protrusion of an intervertebral disc was made by the use of oil in 133 cases and in all except nine the diagnosis proved to be correct at operation. Therefore, the accuracy of his diagnosis by oil myelography was 93 per cent. However, contrary to early opinion, we now know that posterior protrusion of the intervertebral disc can be present and yet not be visualized by oil. This occurs especially when there is congenital shortening of the cul-de-sac or when the protrusion lies too far laterally to indent the sac.

Because lipiodal is not readily absorbed from the spinal canal other contrast media have been sought. Air and oxygen have many enthusiastic supporters.[8,9] There is no doubt that the use of air or oxygen is a valuable adjunct in our diagnostic armamentarium, but the consensus of opinion is that by its use a positive diagnosis of ruptured intervertebral disc can be made in only about 50 per cent of cases. The logical conclusion seems to be that if a contrast medium is necessary for the diagnosis, it is well to try air or oxygen; and if this does not lead to a definite conclusion, oil can later be employed.

As cases of protrusion of an intervertebral disc have been studied, and more information regarding the symptoms and signs presented by these patients have accumulated, greater emphasis has been placed on the neurological findings to determine the presence and the level of the lesion. Localization of the lesion is aided by the fact that in the vast majority of instances, the protrusion is in the lumbar area, particularly in one of the last two interspaces. Spurling and Grantham[27] stated that 99 per cent of ruptured intervertebral discs in their series occurred at the fourth and fifth lumbar interspaces. In an analysis of 500 patients Love and Walsh[19] found that 96 per cent had protrusions in the lumbar region and only a relative few occurred above the fourth lumbar interspace. Spurling and Grantham[27] believed that in fully 50 per cent

of the cases of protruded intervertebral disc, not only could the diagnosis be made, but also the level could be accurately predicted by symptoms and signs alone. They reported that if there is local tenderness of the third lumbar spine associated with hypesthesia and paresthesia in the fourth and fifth lumbar dermatomes, and a reduction or absence of the knee-jerk with the ankle-jerk unchanged, a protrusion is apt to be in the third lumbar interspace. If the localized tenderness is at the level of the fourth lamina with hypesthesia and paresthesia in the fifth lumbar and first sacral dermatomes, and ankle-jerks and knee-jerks uninvolved, the protrusion is in the fourth lumbar interspace. Likewise, if there is local tenderness to pressure over the fifth lumbar vertebra with hypesthesia involving the first and second sacral dermatomes, and a diminution or absence of the ankle-jerk, the protrusion is at the fifth lumbar interspace. It was emphasized that the accuracy and reliability of these neurological signs were proved by the fact that during eight months twenty-six consecutive herniations of the nucleus pulposus were successfully removed without the use of contrast media. While most other neurological surgeons have not relied as much upon neurological signs for the localization of the lesion, yet there is no doubt that some of the protrusions can be localized and removed without the use of lipiodol or air. Semmes[25] reported that he had operated upon sixteen patients from clinical evidence alone and in all sixteen cases the ruptured discs were found and removed. Craig[10] operated upon twenty-seven patients, the diagnosis of protruded intervertebral disc having been made without the use of oil or air roentgenological studies.

One argument against the abandonment of a contrast medium is that a patient may have more than one protruded disc. Camp and Addington[7] have reported that two or more protrusions were present in 12.9 per cent of cases in which the protrusion was diagnosed by lipiodol. It is very doubtful that multiple protrusions would be diagnosed by neurological signs alone and probably can be detected only by the use of a contrast medium.

As experience has been acquired, there has been a definite tendency to simplify operative procedures for protruded discs. At first the laminectomy was as extensive as that usually employed to remove a spinal cord tumor. Two or even three pairs of laminas were removed. Later laminectomy was shortened to sacrifice only one pair of laminas or hemilaminectomy was performed. Still later partial hemilaminectomy was employed, that is, removal of a part

of the lamina above the protrusion and a part of the lamina below the protrusion so that no one single neural arch was completely interrupted. Finally, there have been reports[17] of cases in which the disc was removed by resecting a hypertrophied ligamentum flavum, thus obtaining room to remove the accompanying protruded intervertebral disc without the removal of any bone whatever.

Changes in the postoperative care have been associated with this simplification in the operative technic. For example, patients are kept in bed a much shorter length of time, and immediately following operation they are allowed greater freedom of motion. They may be taken to the lavatory within a few days after operation.

There is still some difference of opinion whether spinal fusion should be done at the time of removal of the protruded disc. The Mayo Clinic Group is quite definite in the opinion that spinal fusion is rarely indicated and recently stated[19] that in only fifteen of more than 500 operations for protruded intervertebral disc was a fusion performed. Certainly there is an economic advantage in not performing a fusion since the period of hospitalization is tremendously increased when fusion is done. I believe that the decision as to whether fusion should be done or not depends largely upon circumstances in the individual case. If such conditions as spondylolisthesis or lumbosacral arthritis exist, a fusion is indicated. Also, if the patient must return to heavy labor, it seems logical that the more rigid his lower lumbar spine, the less chance of recurrence of pain. Thinning of the disc which frequently accompanies a protrusion of part of the disc, may, as Hadley[14] pointed out, produce pain even though the protruded portion is removed. Thinning of the disc may produce pain by: (1) strain upon the ligamentous structures of the articulations, (2) disturbance in the relationship between the articular surfaces, (3) encroachment of the intervertebral foramen with fibrosis about the nerve-root bundles, and (4) bony impingement between the tip of the articular process and the peduncle above or the lamina below.

## CONCLUSIONS

Within the last ten years protrusion of an intervertebral disc has become established as one of the causes of low back and sciatic pain. As experience has been acquired the diagnosis has become easier and more accurate, the surgical procedure simplified and the postoperative care less prolonged.

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## DISCUSSIONS OF PAPERS BY DR. MOCK AND DR. RAAF

FRANCIS C. GRANT (Philadelphia, Pa.): I agree with Dr. Mock in his opinion about the cases of low back pain. Our experience has been that they require careful and detailed study prior to the institution of operative procedures. My impression is that too many operations are being performed for supposed intervertebral disc. Any type of low back pain is now being presumed to be due to this lesion. As Dr. Mock has so well emphasized, if an operation is performed and no disc is found, the final result may be very much worse following the surgical insult than the previous condition.

However, certain cases after close observation present definite indications of the presence of a disc. A history of injury with pain radiating segmentally down the leg followed by repeated attacks of "sciatica," disability of the lower part of the back with tenderness over the lumbar spines and flattening of the lumbar curve, a positive "straight leg raising" test with increase of pain on coughing or sneezing, significant changes in the Achilles or patellar reflexes and hypesthesia or paresthesias in the lumbar or sacral dermatomes all point clearly to a discrete lesion causing pressure on one or the other of the posterior roots emerging in the lumbar region.

Lipiodol has been widely used to confirm or refute the diagnosis of the presence of a disc. Justifiable objections have been raised to the indiscriminate use of this material, but I have not seen the serious results reported by some observers. We have used it whenever we were of the opinion that it was necessary. I know of a number of patients who have gone about unhampered for years with 4 to 5 cc. of lipiodol in their lumbar sac.

The position of the patient on the operating table is important. With the spine in extension the discs tend to recede into the intervertebral space. Slight flexion of the spine causes the maximum protrusion and makes the lesion much easier to identify.

I agree conclusively with Dr. Mock that prior to the identification of an intervertebral disc as a pathologic lesion, many patients with low back pain recovered under conservative treatment. In this connection Henderson's statement is important that only 2 per cent of the patients who

registered at the Mayo Clinic because of low back pain were found to have a disc. My plea in the handling of these cases is definitely for conservatism. Operation should not be advised until all other measures have failed and the history and clinical evidence indicate the presence of a disc very clearly. The results of indiscriminate surgery in cases of low back pain are too disasterous to warrant its use except on very well established grounds.

FRANK H. MAYFIELD (Cincinnati, Ohio): I have enjoyed Dr. Raaf's paper and find nothing in his presentation with which I could disagree.

Protruded intervertebral discs have occupied a considerable portion of my time and interest in recent years. During the past three years I have removed at operation forty-three discs from forty-one patients; thirty of them are entirely well; six feel that they are improved but will not work; the remainder are too recent to record.

We believe that we can diagnose the presence and level of most protruded discs on clinical findings alone and now rarely use lipiodol except in industrial cases in which preoperative verification is required by the Commission before authority for operation can be obtained.

Our experiences with gas spinalgrams has not been so good as reported by others, but the last two cases have been shown quite well by this method and so perhaps our ability to use this technic is improving.

The operation for removal of protruded discs in the lumbar areas has been so reduced in magnitude, as has been pointed out by Dr. Raaf, that the patients are allowed out of bed in seven to nine days and are discharged from the hospital in eleven days. They usually return to work in about six weeks. Among the earlier of our cases, two were fused by tibial bone grafts and neither has had a comfortable back since. A developmental or acquired anomaly of the spine may exist and require fusion, but this should be decided by an orthopedist beforehand, for certainly the operation as presently done creates no defect which in itself requires fusion.

Given a patient who presents the clinical data which Dr. Raaf has quoted from Spurling and his associates, and who has failed to recover under conservative treatment over a period of four to six weeks, I would operate upon him without the use of contrast media.

Cases with doubtful clinical data, of course, require the use of contrast media for verification, but even if the disc is found and removed, the oil cannot be completely removed and is not absorbed; and if the patient should not be entirely relieved, *x*-ray evidence of this residual oil makes impressive evidence before a jury. This medicolegal objection is about the only valid objection to the use of lipiodol in the spinal canal.

There is no reasonable objection to the use of air or other gas in the spinal canal, and we hope to improve our ability to use this method and apply it to doubtful cases.

JOSEPH E. J. KING (New York City): I have enjoyed hearing Dr. Raaf's paper. It is very practical, and full of common sense. I have also

enjoyed listening to Dr. Grant's discussion, and after hearing both, and seeing the lantern slides there is very little for me to say.

The main thing in the discussion of protruded or herniated intervertebral disc concerns itself with the practical consideration and not so much with theory. It is needless to say that every person with a backache or low back pain does not have a protruded disc. It would be equally as foolish to say that everyone who has a pain in the back should have a fusion of the spine performed.

After the diagnosis has been established the operation is rather simple. I think the most unusual fact about this subject is that this condition was not recognized as an entity and understood as it now is until a few years ago. Also, I think that in all discussions of this subject due credit should be given to Dr. William J. Mixter for his splendid paper read before the American Neurological Association several years ago in which he properly described the lesion.

I am not quite sure as to how one should establish the diagnosis. I agree with Dr. Grant that lipiodol should not be injected until one is almost certain of the diagnosis. It is possible that one might almost rely upon the physical signs and neurological examination without injection of lipiodol, but it goes without saying that the use of lipiodol makes the diagnosis more certain.

I have had some experience with the use of air, but I must say it has not helped me much more than ordinary plain *x*-ray films, therefore, I am not able to speak much in favor of injection of air as are some others.

So many writers state that if lipiodol is left in the subarachnoid space it does no harm. This may be true, but I am not yet convinced. I have had opportunities of operating upon several cases in which for some reason or other operation was delayed some time after the injection of lipiodol. In each of these cases I have found that some of the lipiodol injected in the canal had become beaded and imbedded in or alongside the component parts of the cauda equina. Some of these beads or inclusions of oil are about the size of a B.B. shot, and some about the size of a No. 7 bird shot, or even smaller. The little encysted globules of lipiodol were stuck on the side of the component parts of the cauda equina like nitrogen sticks on the roots of a pea vine. I also noticed that the blood vessels of the cauda equina were markedly injected and the roots seemed to be decidedly irritated.

It may be possible that this condition does no harm, but I doubt it. When lipiodol is used, it is my belief that the laminectomy should follow immediately, at which time almost all of the lipiodol can be removed. Personally, I favor the hemilaminectomy advocated by Dr. Alfred S. Taylor. I see no reason for bilateral or complete laminectomy unless the lesion is bilateral. The protrusion of the disc can readily be removed by hemilaminectomy, although it is somewhat more tedious, and I think that the back and spine are much stronger following hemilaminectomy than after complete laminectomy.

Dr. Raaf has covered the subject well and the only question I should like to ask him is this: Is he now able to decide to operate upon these patients who have the classical signs and symptoms without the use of lipiodol; i.e. does he think it is justifiable to do an exploratory laminectomy without the use of lipiodol?

PHILIP H. KREUSCHER (Chicago, Ill.): I am inclined to believe that a large percentage of cases of nucleus pulposus so-called are erroneously diagnosed. I have in mind one surgeon who made a diagnosis of 150 cases of nucleus pulposus seen by him within a year and a half. There is no question but that this condition is a definite surgical entity and gives certain very specific findings. But I fear that we have given the unscrupulous attorney something else upon which to base his claim for damage or injury which is not too clearly understood by the surgeons themselves and not at all by men in the legal profession.

I have seen a number of cases of bona fide nucleus pulposus rupture or protrusion. In two children at the County Hospital this occurred following a spinal puncture where the needle was driven far beyond the canal into the intervertebral space. The findings were typical and symptoms almost immediate. I saw one other case, a football player who had a compression fracture of the third lumbar vertebra, in which the impingement upon the cauda was also definite and immediate.

Not all cases operated upon, even in the very best clinics, get complete relief of symptoms.

I have reason to believe that in some instances a moderate protrusion may not give symptoms permanently since the cord and cauda so often accommodate themselves to the decreased space in the spinal canal. This is definitely seen in cases such as tuberculosis of the spine in which a spinal cord, at autopsy shown to be greatly flattened, had functioned perfectly.

Most of the cases which have come under my observation and which have been diagnosed as nucleus pulposus rupture or protrusion have been erroneously diagnosed as evidenced by the fact that when the settlement was made by the corporation or the insurance company the patient almost immediately recovered.

I think that before making a diagnosis of this lesion one must have a very definite clinical history and clinical findings. We are depending too much upon the *x*-ray and air injection. Lipiodol, in my opinion, should be injected into the spinal canal for diagnostic purposes only when the clinical findings coupled with the *x*-ray findings warrant such a procedure. Following this injection one must be prepared to proceed reasonably quickly with an operative procedure.

I make a plea for a delay in the very early diagnosis of and operation on these cases. One will find that often the spinal cord and cauda will accommodate themselves to an impingement if this actually exists.

EDGAR L. GILCREEST (San Francisco, California): I rise in behalf of the man with a backache who never had a protrusion of an intervertebral disc

or suffered from an arthritis of the spine. I think we ought to hear from that point of view.

I agree essentially with much that Dr. Mock has said. We are all familiar with the old story of the malingerer with the "railroad spine"—that is a sad chapter in medicine. But a slip in a facet causes a disabling backache and we have let the osteopath and the chiropractor cure literally thousands of people with this condition.

At the Southern Surgical Association, in Birmingham, two years ago, I reported 150 cases of backache. Seventy per cent of those patients, as I remember, were cured, most of them in a few weeks, by manipulation. It is not a difficult procedure and it cures the industrial patients as well as the private patients. I have doctors coming to me constantly with low backache which they developed while playing golf or lifting and they become ardent disciples as soon as they are relieved.

The old days of a man with low backache being given a bottle of liniment or a plaster have gone. When one has a slip in a facet, it is just as definite as can be. I have had many strong stevedores and other laborers come to my office, having had a slip occur several days before and during that time they had been at home in bed. They had been unable to lean over and tie their shoes. On examination, one found a contracture of the muscles on that side with trigger points, sometimes pain up in the shoulder, occasionally in the face and about the eye on that side. The patient is put on a table and after the application of heat the back is slowly manipulated with the result that 70 per cent will be relieved. The acute pain will be all gone and just residual soreness left. Many will go back to work in a few days.

This condition has not been generally recognized. I think it is sad that we have let the cultists take a very important part of medicine away from us and I am for returning them to the fold. No association should be more interested in this subject than this one.

HENRY C. MARBLE (Boston Mass.): I did not intend to say anything again this afternoon, but I believe that there is something very definite to be said on this subject. Much as I dislike to do so, I must disagree entirely with Dr. Mock. Are we not reasoning from the back forward?

I must confess more sympathy with the case of the man with a sore back. I think that the man with the sore back has usually a real pain in his back. Once upon a time I had occasion to study a series of a thousand consecutive backaches and less than 2 per cent of them had referred pain down the leg.

I think that the diagnosis of malingering, and other such diagnoses as that, should be thrown in the scrap heap. Now we have after all these years found a cause of a certain small number of backaches, or rather, referred pain down the back. Intervertebral disc is just as real a lesion as appendicitis; and just because doctors do not know enough to make the diagnosis, that does not mean that the man with referred pain down his back is a faker

or a malingerer, or any of those things described by words which I dislike very much.

Dr. Mixter, Dr. Barr and Dr. Hampton, have written extensively on this subject. There have been done in the Massachusetts General Hospital in the last ten years somewhere in the neighborhood of 125 cases for intravertebral disc. In one large Middle West clinic 350 were done in the year 1939 alone, so one would not exactly accuse Boston of being radical. In ten years we have accumulated about 125.

I have talked recently both with Dr. Mixter and Dr. Barr, and they agree with me that the diagnosis of intervertebral disc can be made in a high percentage of cases after a careful, thorough physical examination of the cases, by taking histories and doing physical examinations, by taking careful *x*-rays and a careful medical, orthopedic, surgical and neurological examination, and then a lumbar puncture may aid in finding out the amount of protein present. After this has been done, and *only* after this has been done, after the whole case has been carefully evaluated on the basis of its clinical symptoms, is the matter of whether or not a surgical operation is indicated, discussed or considered.

And, after it has been decided that in all probability a surgical operation is indicated and necessary, then, and only then, should lipiodol be injected.

The use of air, I believe, is of little value. Enough air cannot be put inside the dura to give an adequate column to fill up higher than the fourth lumbar vertebra, so it is practically useless. Enough lipiodol shall be given to fill the space, and in the hands of Dr. Hampton, as has been reported today, about 93 per cent positive diagnosis have been made; after the diagnosis is made, the operation can be done.

Of this group there have been approximately twenty-three so-called industrial cases. They are called industrial cases when the bill in the hospital has been paid by an insurance company; and if my recollection serves me right, seventeen of those twenty-three patients returned to their usual hard labor.

In my personal cases, although I do not do the operation, I have found intervertebral disc is a real, clinical entity, which probably represents less than one-tenth of 1 per cent of the backaches that come into a doctor's office.

Dr. Barr told me recently that of the patients who came to his office, about 20 per cent were ultimately found to have intervertebral discs; and when you consider that probably he got only a very small percentage of the patients with backaches who went to doctors, this is only a tiny part of the matter of low back pain.

CHARLES C. GREEN (Houston, Texas): It is with a certain amount of temerity that I rise to disagree with such an eminent surgeon as Dr. Marble. He has taken an extreme view of the problem and I must disagree

with him. I have had many a headache because of backaches from trauma, with only subjective symptoms.

There is no doubt in my mind that many backaches are the result of a misplaced disc and since we have learned to diagnose this lesion a great number of cases, formally thought to be the result of malingering instead of trauma will be relieved. But I have seen numbers of backaches and similar conditions go on without improvement in spite of all character of treatment only to clear up entirely after having a satisfactory claim adjustment.

I call to mind a supposed brachial plexus injury claimed to have been received by a Mexican employee of the railroad. He was in the hospital for twelve months under the care of capable doctors but he did not improve. At the end of twelve months he was dismissed and told we could give him no further treatment. Two or three days later the Mexican Consul called on me insisting that he be given his total and permanent disability insurance. I refused to allow it but told the Consul that if he would get this Mexican to submit to a simple test I could prove that my position was correct. He accepted my proposition and the Mexican was carefully anesthetised to a surgical degree of anesthesia. He was then allowed to recover from the anesthetic until his reflexes returned and then I saturated the cone with ether and put a wet towel over the mask in such a way as to cut off all air, the patient began to struggle for air and we held his unaffected arm and finally he reached up with the supposed paralized arm, pulled the mask from his face and held it up in the air until I told the Mexican Consul to take it.

This was proof enough so the Consul dropped his claim. But for months he continued to walk around Houston with a useless left arm and a spastic paralysis of the left leg. A day or so before I left Houston for this meeting I was at lunch at the Rice Hotel and this supposed paralized Mexican was my waiter and was carrying a heavy tray of dishes with his left arm. When he saw I recognized him, he told me he was well and asked if I thought the railroad would give him his job back. I told him "Hell, no."

This is a concrete example of where a corporation would have been done a grave injustice unless it had been so thoroughly demonstrated to the Mexican Consul that his man was faking, so we must be very careful to work out cases and determine which are real cases of pain and which are malingerers.

JOHN D. ELLIS (Chicago, Ill.): In discussion of these excellent and comprehensive papers there are so many interesting aspects to consider that one might easily go far afield and I shall emphasize only a few of the important points that have been made.

Systematic and general examination of the "industrial back" is our only means of avoiding such embarrassment, as is represented by Dr. Mock's lantern slide, showing a splendid low back fusion inadvertently performed upon a case of carcinoma of the prostate with metastases scattered in the spine and pelvis.

Repeated examination over a prolonged period is our only safeguard against overlooking a cord tumor or posterior herniation of a disc. When first seen, the patient's symptoms may be entirely subjective. An examination made later will show the objective finding of changes in reflexes, and skin sensation, loss of muscle tonus or wasting, etc.

The head of the surgical department of one of our universities recently told me he dreaded to give an opinion on a minor back injury case for fear of overlooking a cord tumor before definitive signs had developed. Every surgeon that treats so-called "industrial back" cases is likely to find himself becoming an internist. In this connection, the report of Dr. R. T. Johnstone, director of occupational diseases at the Golden State Hospital in Los Angeles, is interesting. He has recently had the opportunity of making a systematic study with unlimited laboratory investigation of 3,018 consecutive workmen, claiming compensable disability from back injuries. He denied compensation in 70 per cent of these, based on the finding of definite nontraumatic causes of the disability and concludes that from an internist's standpoint "industrial back" is not primarily an orthopedic problem but one for differential diagnosis.

Dr. Mock outlined osteoarthrosis. There is a medicolegal point here to which we could all afford to give some thought. If we could distinguish in our terminology between degenerative joint diseases, not in themselves painful, by using the term "arthrosis," as all the continental medical literature does, and "arthritis," an inflammatory disease, discarding entirely the English term "osteoarthrosis," we would be in a much better position to explain at a Compensation Board hearing our distinction between painful and nonpainful spinal conditions.

Both papers raise another question of medicolegal importance. How can we controvert a claim before the Compensation Board that the presence of lipiodol in the spinal canal may in itself be productive of disabling symptoms? To mention only a few recent reports in the literature, Drs. B. R. Young, M. Scott, and A. F. Lindholm could be cited to prove that the oil may have a permanent deleterious effect. It is difficult to get every globule of lipiodol out of the dural sac even at operation. However, if no lipiodol has been injected it is often unnecessary to open the dura in the removal of a posteriorly herniated disc.

Fortunately, in one case in which this oil was left in the spine after an examination which revealed no herniation, I was able to extract most of the oil by placing the patient in a sitting position and introducing a curved trocar, used in nasal surgery, into the sacral hiatus. The lipiodol is heavier than spinal fluid and by having the patient cough repeatedly most of the oil flowed out.

It strikes me that in industrial cases it is preferable to operate "on suspicion" than to leave any considerable radioopaque material in the canal.

The statistics bearing on the frequency of posterior disc prolapse are misleading. When a new clinical entity, such as this, is discovered, many

cases are soon reported in the literature. One clinic after another reports a series of cases operated upon, and the relative frequency of disc prolapse in proportion to the other back conditions seen in each clinic rises. This does not mean that the actual percentage of back injuries presenting disc pathology increases. It means only that the published lists of cases induce the medical profession in that particular vicinity to send into the clinic for operation more and more disc herniation cases.

In a way such medical literature is an advertisement, making an appeal for certain surgical work to be sent to the author and should be regarded as such. This is not said in disparagement of the excellent work of Camp, Love or Adson, but only to call attention to the fact that the apparently increasing percentage of back cases they see needing operation for posterior disc herniation is due to the fact that such pathology is diagnosed by the referring physician, and the patients are sent in because they need operation. Actually the condition is rare. The only way to judge its frequency is by study of a large series of autopsies on the spine, such as that of Schmorl, of Dresden, who routinely examined about 10,000 spines. Eighteen of these presented small and generally multiple posterior prolapses not large enough to displace the cord; two were traumatic, one from a stab wound and one associated with severe vertebral injury.

HARRY E. MOCK (closing): This discussion was centered chiefly around the nucleus pulposus. In the excellent movie shown here we have witnessed an example of the protrusion of this nucleus in a case in which operation certainly was indicated. This example bears out the statement in my paper that good conservative surgeons are finding definite protrusions of the disc, giving very definite neurological findings which require operative intervention.

I mention cord tumors because this condition represents a pathological entity which gives definite neurological signs and symptoms and yet the diagnosis is missed so frequently. Too many of these patients have been allowed to suffer for months and years before the true diagnosis was made and the condition relieved by the necessary operation. No one in the past, and few of us today, would advocate exploratory operations on patients with indefinite but persistent back pain and sciatica in order to ascertain whether or not they had a cord tumor. The profession has demanded that cord tumors be recognized by the presence of very definite neurological findings, and until these findings exist operation is not indicated.

I feel very strongly that the protrusion of the intervertebral disc into the canal should give definite neurological findings, comparable to the situation in cord tumors, before we subject these patients to operation.

In reality, Dr. Marble does not disagree with me one iota in my condemnation of nucleus pulposus operations. I agree with him that there are conditions in the spine that give such definite symptoms that good team work between the orthopedic surgeon and the neurological surgeon usually

can give relief. Not one word have I said condemning operations on these patients.

I must strongly condemn the growing tendency, prevalent all over the country, to diagnose nucleus pulposus derangements when patients with low back pain are found to have *x*-ray evidence of a slight concavity in the inferior or superior surfaces of one or more of the vertebral bodies. Too many of these patients are being told by their doctors that they have this new disease, herniation of the nucleus pulposus, or that this disease is strongly suspected. In lieu of calling such conditions a slipped sacroiliac joint and placing the patient in a back brace, too many of these doctors are referring them to this or that specialist or this or that clinic because of this suspected new disease. Too many doctors are saying, "I must take you to the hospital and inject lipiodol and then you will probably have to be operated upon." Most of the patients do not follow these directions but drift into other hands. But the damage has been done, the seed of phobia has been planted in their minds and it is almost impossible to get rid of the back pain as long as this fear of some obscure condition in the spine which may require operation exists.

One of the discussors said today that fusions of the spine were becoming altogether too popular but this popularity has been checked by this new operation. This is a confession of a change in surgical style that I do not want to see happen with this condition—a condition that is so extremely definite when it is present. But we are bound to have this operation condemned as a fad if we keep on diagnosing herniations, protrusions and other nucleus pulposus disturbances in the thousands of low back pains that are occurring every day the result of the same ordinary conditions that have caused low back pains throughout the centuries.

I beg that, before jumping to the conclusion that trauma is the cause of the low back pain and before advocating a radical operation upon the back, we investigate every case so thoroughly that the kidney stone, gallstone, fibroid, metastatic carcinoma or the numerous other conditions in other parts of the body that can cause low back pain will not be overlooked if present. It is just as faddish, just as detrimental to give short wave diathermy, lamp treatment or other forms of physical therapy to such a back when other conditions in other parts of the body are responsible for the trouble.

I deeply appreciate the very frank discussion of my paper.

JOHN RAAF (closing): The controversial point of whether lipiodol, if left in the spinal canal, can produce untoward effects is of considerable interest. For instance the Oregon State Industrial Accident Commission favors removal of the lipiodol even in those cases in which studies are negative. The reason for this is fear of litigation over its presence in the spinal canal rather than conviction of it actually producing symptoms.

I have removed lipiodol from several patients who were not operated upon for protruded disc. An *x*-ray should be taken to visualize the end of

the dural sac. With the patient in the sitting position a small burr hole can be placed in the sacrum and the tip end of the sac opened. If the patient is in this position the lipiodol can be removed practically in its entirety.

The importance of the patient's position on the table during the operation, which Dr. Grant has mentioned, was exemplified to me in a case in which the disc was exposed, but before it could be removed it disappeared. Hyperextension of the spine failed to make it reappear. When the spine was flexed, however, a clamp could be inserted into the disc and the portion which had formerly protruded was withdrawn.

Discs located at the fifth lumbar interspace are difficult for me to visualize with air and therefore I do not think air studies can be conclusive in these cases.

Dr. King asked whether I would operate for protruded disc without the use of lipiodol or air. As yet I have not operated upon any patients on the basis of neurological signs and symptoms alone. Just before leaving Portland I saw a patient for whom I advised conservative treatment. Should this patient eventually come to surgery, I would be willing to operate without the use of air or lipiodol because the symptoms and signs were typically those of protruded intervertebral disc.

A history of severe injury to the spine is not necessary for the diagnosis of protruded intervertebral disc. Naffziger and his associates have estimated that when a person lifts a fifty pound weight, 500 pounds of pressure are exerted on the lower lumbar discs. From this deduction one can assume that repeated strain upon these discs incident to every day work is enough to produce protrusion of a disc. Furthermore, I believe history of intermittent pain is more important in making the diagnosis than history of a single severe back injury.

Why does the patient have intermittent symptoms? One reason, as has been pointed out, is that the protruded portion of the disc may slip back into place, thus relieving the pressure on the nerve root. Another factor is that at intervals the disc may become edematous and enlarged.

I was glad to hear Dr. Marble state that Dr. Barr proved the diagnosis in only 20 per cent of the patients who came to his office with the presumptive diagnosis of protruded disc. This corresponds to my own experience in which only 13.47 per cent of those who were at first suspected of having protruded disc were operated upon.

I certainly do not believe it is advisable to defer operation until these patients have developed all the signs and symptoms of spinal cord tumor, for many patients with protruded disc never develop symptoms other than pain.

I wish to thank all those who took part in the discussion.

# THE COMPATIBILITY FACTOR IN THE TRANSFUSION OF BLOOD*

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THE transfusion of freshly drawn blood is still attended by a mortality and morbidity which should be matters of serious concern to everyone engaged in this work. The exact incidence of these tragedies as they occur in the hands of thousands of practitioners who are transfusionists is unknown, because they fail to record and publish their results. Data concerning only a small fraction of the transfusions which are currently performed are available for study. These reports come for the most part from the better hospitals and clinics where the results are notably superior to those which are generally prevalent. The information even from these sources is often incomplete. Typical of these data are the following reports: Hesse and Filatov[1] in 1933 reported from Leningrad a mortality of 1.3 per cent among 750 transfusions. According to DeGowin[2] seven deaths occurred among 3,500 citrated blood transfusions performed at the University of Iowa Hospital from November, 1933 to July, 1937, an incidence of 0.2 per cent. In 1936, six reactions of incompatibility occurred in about 2,000 transfusions performed at Bellevue Hospital, New York, during the preceding six years, an incidence of 0.3 per cent.[3] In the same year six deaths were reported from one British hospital during a period of only two and one-half years.[4] Among 3,295 transfusions performed at the Mayo Clinic during 1938 the incidence of the definitely untoward and severe reactions amounted to 0.4 per cent.[5]

Probably quite typical of many observations is that of Dameshek[6] who, in December 1938, wrote as follows: "Within the past year it has been my sad privilege to see in consultation at five different hospitals in and around Boston as many serious transfusion accidents. The first four were fatal; the fifth undoubtedly would have been had not the surgeon withdrawn the needle when the reaction occurred. . . . Since this is solely my own experience, it is certain

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that other such serious accidents have occurred in this and nearby communities, and that most of them have gone unreported."

In most instances in which freshly drawn blood is given the authors admit that these disasters are due to blood incompatibility. Occasionally, however, an attempt is made to prove the contrary but like Bordley[7] in 1931 we have not found since that date a single case report with "complete and satisfying evidence to prove that the blood of the donor was compatible with that of the recipient."

Seldom are transfusion deaths and morbidity any longer due to technical errors of the transfusionist or to his employment of dangerous apparatus. The other possible or alleged causes of trouble such as allergy, tendency toward thermic reactions, susceptibility to shock and renal disease are rarely if ever proved to be the actual or even the probable disturbing factors when freshly drawn blood is given.

It is in the clinical laboratory instead of in the operating room or at the bedside that errors are committed which give rise to practically all of the present day transfusion mortality and morbidity. The prevalent technic of administering blood is highly satisfactory but the prevalent technic of examining it is quite unsatisfactory. Because of this, blood transfusion in most places has not yet been robbed of all dangers attending its use. This is particularly regrettable because reliable and practical laboratory tests have been known and given wide if not repeated publicity for nearly a quarter of a century. Thus Lindeman[8] wrote as follows in 1916: "By careful, accurate and complete hemolysis and agglutinin tests, when the work is done skilfully, blood transfusion is robbed of all danger attending its use." He emphasized the importance of skilful laboratory work and described a technic for compatibility determination which he and others since have employed with the utmost satisfaction. Lindeman's contribution did not cause a general elimination of the evils which existed then in connection with this work and which have persisted in most places up to the present time. They are two, namely, unskilful laboratory work and the employment of tests which do not meet all the requirements for safety.

In many of our better hospitals and clinics, to say nothing of the less favored ones there is a deeply rooted custom of relegating the clinical laboratory work to individuals whose training and experience are not sufficient to enable them to perform skilfully and with safety all the tests which are assigned to them. Compatibility tests fall into a category of laboratory procedures which require a con-

siderable amount of time and experience under expert supervision for the development of satisfactory skill in their performance. These tests do not permit of unchecked errors without possible and probably grave consequences to the patient. Now it is a well known fact that interns as a class spend too little time in the clinical laboratory even when under expert guidance to become more than tyros in this work. Yet they alone are responsible for these vital tests in many places and as seniors on the laboratory service may furnish their juniors with the only instruction which they receive in compatibility tests. As already intimated the fault here lies with the briefness of the laboratory service and the inferior training and supervision given. These critical remarks are applicable also to technicians. We know, however, that the latter, as a class, with far less formal laboratory training in the basic sciences than the interns have, are capable of becoming satisfactorily proficient in this work after a period of several months of intensive training under a competent clinical pathologist who is indispensable for any safe and satisfactory plan.

A recent survey of blood transfusions in America conducted by questionnaire mailed to about 700 hospitals approved for internship under the authority of the Blood Transfusion Betterment Association of New York City, netted 350 replies which indicate, according to Levine and Katzin[9] that in the selection of donors five depend upon blood grouping alone, thirty upon direct matching alone, of which only three include cross-matching and 310 employ both grouping and direct matching of the donor's cells with the recipient's serum.

Now all of these tests, as usually performed, are unsatisfactory for the detection of hemolysis. The fact is that they are employed almost universally for the detection only of red cell clumping with little if any regard for evidence of red cell destruction. The latter evidence as seen in these tests, such as increased transparency of the mixture and the shadow-like appearance of red cells is not sufficient for accurate and consistent recognition even by experienced individuals. It is unsafe, too, to assume the sufficiency of the agglutination reaction alone on the basis of the idea as expressed by Moss[10] in 1910 that "iso-agglutination may occur independently of iso-hemolysis but iso-hemolysis is probably always preceded or accompanied by iso-agglutination." Contrary to this view there is evidence of the occurrence of hemolysis without preceding agglutination. However this may be, experience has proved the necessity for tests

for hemolysis which are more reliable than the ones under consideration here.

Detection of the hemolytic factor of incompatibility is of such vital importance because practically all transfusion deaths as they are now reported are characterized by massive hemolysis.

Blood grouping alone is quite unsatisfactory for several other well known reasons such as the proneness of the grouping sera to deteriorate in titer and to give rise to errors thereby, its failure to provide controls for the checking of errors and the conformation of the test to the erroneous assumption that there are only four blood groups when, as a matter of fact, there are subgroups for the detection of which more accurate tests than standard blood grouping are necessary and important.

Direct matching does not check the reaction between the cells of the recipient and the serum of the donor, a possible reaction in vivo, which can not be ignored with safety. Cross-matching obviates this fault but like direct matching it is a relatively crude test as it is described in most textbooks and as it is performed in most places. A drop of serum is mixed with a drop of red cell suspension. If the agglutinin titer is low and the concentration of red cells is high, no agglutination is likely to occur even in the presence of factors of incompatibility.

In view of these several serious shortcomings of the above tests it is highly desirable to discard them for safer ones such as that described by Lindeman, which has the incomparable advantage of being absolutely reliable and at the same time simple enough to be performed by any reasonably intelligent and properly trained technician. It automatically excludes errors resulting from the crudest kind of technical mistakes in blood grouping to the more confusing errors theoretically caused by minor differences within the blood groups. It thus conforms to all the known and unknown groups and subgroups of blood and reveals at one and the same time in a readily detectable manner incompatibilities of both iso-agglutination and isohemolysis.

This technic was introduced into the clinical laboratory of St. Luke's Hospital, Chicago, by Dr. Edwin Hirsh[11] in 1924 and into the clinical laboratory of Trinity Hospital, Minot, in 1932 by Dr. P. J. Breslich, who trained under Dr. Hirsch. This method of compatibility determination has resulted in the complete elimination in both hospitals of serious transfusion reactions in all cases in which it has been employed. The number of transfusions performed annually at

St. Luke's Hospital is approximately 600 and at Trinity Hospital 200; all told, therefore, about 9,000 blood transfusions have been given at St. Luke's Hospital and 1,600 at Trinity Hospital without the occurrence of a single disaster.

Lindeman's technic of hemolysis and agglutinin tests as employed at St. Luke's and Trinity Hospitals has been modified somewhat but not in any of its essential details. It reveals in test tubes all the noteworthy reactions of incompatibility which occur when saline suspensions of red cells are mixed with different dilutions of serum and are permitted to stand at room temperature for one and one-half hours. Cross-examinations are carried out in this fashion between the red cells and sera of both the patient and the recipient. Control reactions are run between red cells and saline solution alone, and between the red cells and serum of the same individual.

Preliminary typing or blood grouping is carried out routinely for the purpose only of selecting for the actual compatibility tests individuals of the same blood group as the patient. Only members of the same group are so tested. Since blood grouping in our hands is never relied upon for the actual selection of donors, an error in this regard causes the patient no trouble, where otherwise it might cost him his life.

It is necessary to determine compatibility before each transfusion when it is repeated regardless of whether the same or other donors are to be used because of the occasional occurrence following transfusion of incompatible factors which otherwise will not be discovered.

Blood in the amount of 10 cc. is withdrawn for the examination. It is divided and to 2 cc. are added oxalate crystals to prevent clotting. The serum from the remaining portion is recovered after separation from the clot. The oxalated blood is centrifuged and the cells removed. They are washed in physiological saline solution three times to rid them of serum. The final packed cell mass in the centrifuge tube is converted into a 5 per cent suspension by the addition of saline solution.

Ten test tubes are arranged in numerical order in a rack. (Fig. 1.) Into each of tubes 1, 2, 3, 4 and 5 is placed 0.1 cc. of a 5 per cent saline suspension of the donor's erythrocytes. To each of tubes 1, 2 and 3 is added the recipient's serum in the following amounts, respectively: 0.1, 0.2, and 0.4 cc. Four-tenths of a cubic centimeter of the donor's serum is added to tube 4. Into each of tubes 6, 7, 8, 9 and 10 is placed 0.1 cc. of a 5 per cent saline suspension of the

recipient's erythrocytes. To each of tubes 6, 7 and 8 is added the donor's serum in the following amounts, respectively: 0.1, 0.2 and 0.4 cc. Four-tenths of a cubic centimeter of the recipient's serum is

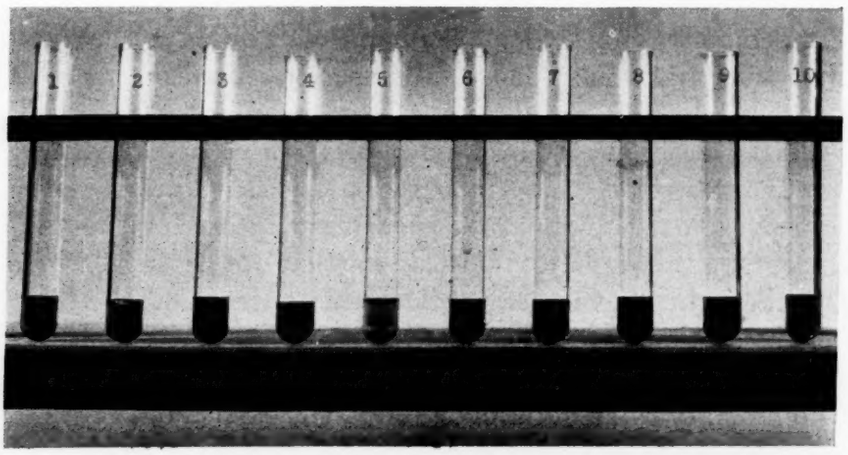


FIG. 1. Photograph of the rack of ten test tubes sometime after completion of the mixtures. Final reading for agglutination and hemolysis is made only after the expiration of one and one-half hours.

added to tube 9. Physiological saline solution is added to the 10 tubes in amounts sufficient to make the content of each equal to 1 cc. In tubes 1, 2, 3, 6, 7 and 8 occur the cross reactions between the serum of both the donor and the recipient in three different dilutions and their erythrocytes. In tubes 4, 5, 9 and 10 occur control reactions between serum and erythrocytes of the same origin in saline solution and the erythrocytes alone of both the donor and the recipient.

CHART 1

| Tubes No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Donor's erythrocytes 1–20 dilution | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | | | | | |
| Donor's serum | ... | ... | ... | 0.4 | ... | 0.1 | 0.2 | 0.4 | | |
| Recipient's erythrocytes 1–20 dilution | ... | ... | ... | ... | ... | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| Recipient's serum | 0.1 | 0.2 | 0.4 | ... | ... | ... | ... | ... | 0.4 | |
| Physiological saline solution | 0.8 | 0.7 | 0.5 | 0.5 | 0.9 | 0.8 | 0.7 | 0.5 | 0.5 | 0.9 |

This chart shows the exact content of each of the ten tubes employed in the compatibility test.

After preparation, the tube mixtures are allowed to stand for one and one-half hours. Delayed reactions are not uncommon. Incompatibilities, if present, are usually apparent within forty minutes but, for absolute safety, the full one and one-half hour observation period

is necessary. In approximately 4 per cent of tests between bloods of the same group incompatibility is found which is usually due to agglutination unrevealed by the blood grouping tests but occasionally to hemolysis. If the macroscopic evidence of agglutination is at all doubtful—a rare event—a microscopic examination may be carried out. In no case, however, has the microscopic examination in our hands given additional information, but several hemolytic and agglutination reactions were demonstrated in the test tubes macroscopically which were not found upon microscopic examination.

Compatibility determination by means of this technic requires more time and effort than do the procedures in common use. The time element, however, is not greatly in excess of that required for the necessary preliminary examination for syphilis. The factor of time is important only in so far as it concerns the welfare of the patient. It is high time that clinicians concede this point and act accordingly by ceasing their unreasonable demands for speed in the laboratory which precludes the use of safe methods in these preliminary tests. Their reasonable and wise anticipation of the possible or probable necessity for blood transfusion before an emergency occurs will avoid in most instances the unexpected necessity for immediate blood transfusion without sufficient time for safe and accurate laboratory tests. Where provisions of this kind are impossible, temporary substitutes for blood, like saline solution, is in our opinion much better for the patient often times than is blood which has been hastily examined by a fallible method. Too often such examinations are performed by nervous and improperly trained interns and technicians whose incompetence is accentuated appreciably by the unreasonable demands for speed made by the clinician.

Of course it is conceded that the condition of the patient does at times necessitate the immediate administration of blood with acceptance of the risks which this procedure involves. This fact, however, does not justify the disregarding of vital safeguards whenever it can be avoided with greater safety to the patient.

## CONCLUSIONS

1. A noteworthy percentage of severe and fatal reactions still attend the transfusion of freshly drawn blood.

2. These reactions are practically all due to factors of incompatibility.

3. The prevalent methods of examination for these factors are not sufficiently accurate to reveal their presence invariably.

4. Lindeman's technic of "careful, accurate and complete hemolysis and agglutinin tests, when the work is skilfully done"[8] always reveals the presence of these factors when they occur.

5. Lindeman's technic is practical of application and because of this and its incomparable superiority should replace all other methods of compatibility determination now in general use.

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# SEVERE INJURIES OF THE FACE AND JAWS*

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LARGELY because of our mechanized adjuncts of living, injuries of the face and jaws are on the increase. The auto "guest-passenger" injury is one outstanding example. Necessity, therefore, has demanded a greater surgical activity. This has in turn, been reflected in the literature of the subject. Among the recent contributions one should mention the work of Blair, Ivy, Kazanjian, McIndoe and Brown.

For two reasons in particular adequate early repair and replacement—an essential objective of the surgeon—may not be given. Under the conditions often encountered in the first instance, namely, early swelling which tends to mask the true nature of the injury, inadequate treatment is avoidable. In the second example, the condition of the patient may be such that the general effort to save his life rightly takes precedence.

## EARLY CARE OF THE SOFT TISSUES

Within the first twelve hours with certain exceptions such as large lacerated wounds, markedly contused wounds and deep wounds of the floor of the mouth, the aim of the surgeon should be to affect thorough cleansing of the wound, remove any foreign bodies, remove evidently devitalized tissue and to effect a closure with the objective of getting healing by primary intention and in some instances, when tissue loss is present, to affect a suitable plastic repair. After twelve hours, often it may be wisest to approximate only loosely the soft tissues which allows some provision for drainage or even to allow the wound to heal by secondary intention without any attempt at approximation. For large, severely lacerated wounds or contused wounds, the surgeon often will obtain a better final result if some time is given for the damaged tissue not entirely destroyed to recover its vitality, and for the devitalized tissue to separate. In certain large, lacerated wounds, sometimes for the purpose of retaining position, very loose approximation of the tissues may be a wise procedure.

*From the Department of Surgery, University of Kansas School of Medicine. Read before the American Association for the Surgery of Trauma, June 7–8, 1940.

For the ordinary incised or lacerated wound, cleansing the wound under continuous irrigation is most satisfactory. Any dirt or oil ground into the skin which may produce tattoo marks must be

A B

FIG. 1. A, patient who had her nasal bones crushed posteriorly. The anterior maxillary bone was crushed into both ends of her antri on either side. The skin of the nose was badly lacerated. The nasal bones were elevated and both antri were entered through the canine fossa and the wall was pushed forward. The lacerated skin wound was converted into an incised wound and was carefully sutured with fine interrupted sutures. B, the amount of scar present after a year had elapsed.

removed by scrubbing with the proper solvent. Deeply imbedded grains of black powder should be picked out. It is the rule that all foreign bodies should be removed, but deeply imbedded bullets and multiple shot may demand a contrary decision. In general, little débridement should be done about the facial region beyond very slight trimming of shreds, and evidently devitalized tissue and the trimming of skin so that the edges may be brought to each other at perfect right angles. The mandate for careful immediate layer suture applies to "trap door" flaps, scalp flaps, cuts through the ears and eyelids, all narrow double-surfaced flaps such as the border of the eyelid, all through-and-through cuts and tears of the skin, cartilage and mucosa of the nose, large clean cuts in the tongue and mucosa of the cheek. As a rule, it is unwise to suture the floor of the mouth unless adequate inferior drainage is given. The suture of motor nerves of the face is usually not practical. They are too thread-like. When a local area of contusion is present other parts of the wound may be sutured. When a flap has been formed, and one is in doubt of

its blood supply, the flap should be laid in place and held either by a very few tacking sutures or by gentle pressure or both.

All effort to prevent suture marks should be made after the suture

A B

FIG. 2. A, a wound in which approximation due to early swelling when the patient was first seen was not entirely accurate. It will be noted that she also shows some suture marks. B, "Trap door" flap of the forehead. It is to be noted that even with the most careful suturing she still has a slight tendency to elevation.

of facial wounds. As a rule, fine interrupted skin sutures should be placed with fine needles about one-eighth of an inch apart in such a manner that the skin is coapted at an accurate right angle. (Fig. 1A and B.) Every other suture may be removed on the third day and usually all sutures should be removed by the fourth or fifth day. Strips of bandage gauze saturated with "Ace" adherent will give considerable support if applied immediately after the removal of sutures when one doubts the stability of the wound. When deep approximation or tension sutures are advisable, they should be tied over dental rolls. If left in situ longer than four days, a mark will be left where the suture was placed through the skin. (Fig. 2A.) Deep through-and-through sutures tied over a dental roll may be a very efficient method of obliterating a dead space or to hold two parts of a structure from spreading, as for example, the bases of the nose after a severe crushing injury.

"Trap door" flaps with bevelled edges often present a special problem. (Fig. 2B.) Due to underlying scar which tends to contract and the thin edge of the derma which tends to shrink, a humped up pad of skin and subcutaneous tissue surrounded by an unsightly scar is likely to form. Usually, one may affect a repair after a trap door flap is raised by excising the circular scar and the dermal base at right angles. Two small v-shaped excisions are made at either end of the horse-shoe shaped external circumference to limit its length.

The skin edges are now carefully approximated by suture and a pressure sponge dressing is applied for ten days.

Occasionally, after loss of the soft tissue one may save time by

A B

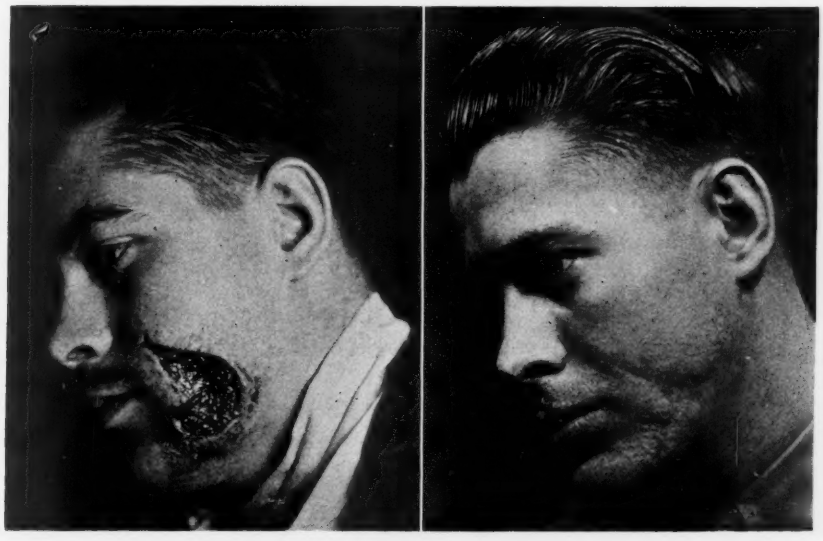
FIG. 3. A, example of immediate switching of an artery flap from the lower to the upper lip. B, photograph taken two weeks after the flap was switched to the upper lip.

immediately switching a skin flap into the defect from some appropriate neighboring area. (Fig. 3A and B.) This may occur particularly after loss of a part of either lip or part of the scalp. When a sufficient amount of the scalp has been lost so that closure cannot be effected, the application of a skin graft to the periosteum is an advisable procedure. At times, a very successful closure of a defect of considerable width with definite tissue loss may be made by approximating sliding advancement flaps. (Fig. 4A and B.)

### THE TREATMENT OF HEALED SOFT TISSUE INJURIES

Secondary repair, after healing of the soft tissues is complete, may be advisable whenever a wide or depressed scar may be converted into a hair line scar and the contoural defect can be eliminated by approximating the deeper, soft tissues. Secondary repair is also indicated when at the primary repair either the soft tissues were not replaced in their proper position or some distortion has resulted from loss or displacement of the tissues. When suture marks are present following careless primary suture, the surgeon is likely to be more embarrassed because of the suture marks which cannot be removed than by the scar of the primary injury which as a rule can largely be obliterated.

For the repair of soft tissue defects which cannot be repaired by simple excision and resuturing, the reconstructive surgeon has two sources of material: skin grafts and skin flaps.



A B

FIG. 4. A, example of method of closure of a wound by sliding and advancing flaps adjacent to the wound. B, result six months later.

A B

FIG. 5. A, example of a large scar with some ectropion of the lip and corner of the mouth which was excised and resurfaced with a thick skin graft. B, final result.

For the coverage of wide, purely surface aseptic denudation a thick intermediate skin graft is usually preferable (Fig. 5A and B), but when there is some contoural defect, a skin flap should be selected as a rule. (Fig. 6A and B.) It is necessary that there be an adequate buccal, labial, mucosal or skin lined sulci if the jaws, lips, tongue and cheeks are to perform their natural function.

For the reconstruction of an intraoral lining defect or an atresia of the nostril, correction as a rule can be given by crosscutting the limiting cicatrix followed by resurfacing of the raw defect with a skin

A B

FIG. 6. A, example of a full thickness destruction of the cheek in which some contoural replacement was done by means of a flap of skin and subcutaneous tissue from the neck. B, final result.

graft held in place with a stent. When the intraoral limiting cicatrix is at the posterior angle between the upper and lower jaws, often the use of a flap will give a better functional result than the use of a stent skin graft, as the latter tends to contract to a greater extent than the skin flap. For the building of organs a skin flap has no competition when requiring thickness, for filling a depression in the soft tissues, for building a part requiring two soft pliable epithelial surfaces and some thickness and as a direct covering for bone or cartilage.

### TREATMENT OF RECENT FRACTURES OF THE BONES

As a general rule the distortions due to fractures of the bones of the face and jaw should be corrected early. But an exception to this rule is when the cribiform plate is fractured.

### RECENT FRACTURES OF THE FRONTAL BONES

When the frontal bone has been crushed inward, the indication if the condition of the patient permits, is elevation of the depressed nose. A crushed in frontal sinus may be pried out by inserting a chisel into the sinus just under the orbital border.

### RECENT FRACTURES OF THE NASAL BONES

Fractures of the nasal bones fall roughly into two groups: (1) simple lateral displacement and (2) crushing of the nasal and septal

bones alone and possibly in addition crushing of the nasal, maxillary, lachrymal and ethmoidal bones. After simple lateral displacement or moderate crushing of the nasal bones per se as a rule, it is a fairly simple matter to remold the bones as well as the septal cross-lap laterally or forward to a normal position. Although simple packing forward and upward has been depreciated by Blair as a means of support, it would seem that the method has some value if done thoroughly until sufficient time has elapsed for some cellular infiltration to effect some degree of immobilization. When the crushing force has been such that a varying amount of the nasal, maxillary, lachrymal and ethmoidal compound is involved, one should ascertain by radiographic studies whether or not the cribiform plate of the ethmoids is involved. If so, early replacement is contraindicated. Otherwise early replacement is indicated, and usually can be effected by the nasal route alone; but when the frontal processes with the anterior lachrymal crests of bone are flayed outward into the orbit some instrument, such as a lion jaw forcep which will give mesial compression, should be used. In the severer types of crushing injury of the nasal compound, a simple intranasal pack does not give sufficient support forward and when the frontal process as well as the lachrymal crests or bone has been flayed outward, it is necessary also to prevent lateral spread. The first objectives can be attained by applying a plaster head cast with a heavy wire projecting forward. A very small drill or an awl is then passed through and through the nasal bones. Through these perforations a fine loop of steel wire may be made through the nasal bone to hang over the projecting heavier wire. To prevent lateral spread through a similar perforation a second fine steel wire is passed through and through the frontal processes of the maxillae as near the base of the whole nasal arch as possible. The wires should be passed over some object such as a small rubber rube to prevent cutting of the skin.

### RECENT FRACTURES OF THE MAXILLARY COMPOUND

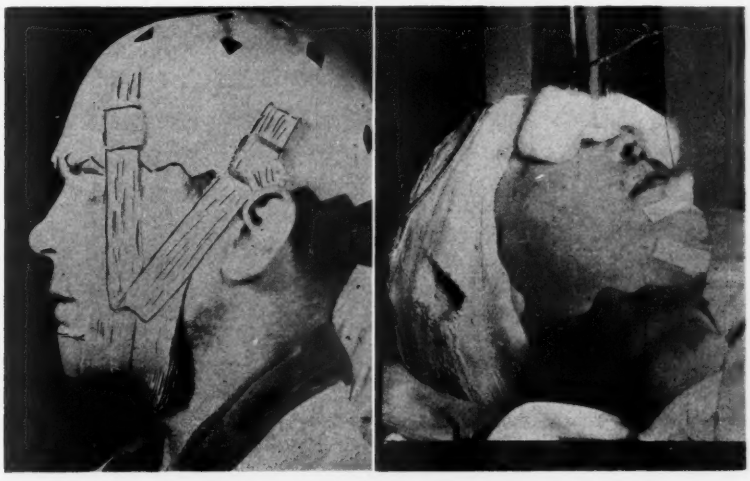
Fractures of the maxilla in so far as treatment is concerned fall into two groups: fractures of the alveolar process and palate and fractures of the superstructure proper. A segment of the alveolar process, which may include the body of the maxillae, may be pushed bucally, labially or lingually. To correct this fracture, one should wire the teeth of the same part of the jaw to the corresponding teeth of the lower jaw after proper fixation by interdental wiring of the upper

unsound segment. Fracture of the transverse process of the maxillae upward and nasalward requires replacement by means of pressure on the floor of the nose. Fracture of the maxillary superstructure includes any part of the loculate mass of bone made up of the maxilla, the lachrymals, the lateral masses and nasal plate of the ethmoids and the pterygoid plates of the sphenoid. These fractures fall into three classic types: (1) The first type of fracture is preceded by a telescoping fracture of the nasal bones. In addition to the nasal bones, the frontal processes of the maxilla are comminuted and crushed and the inner half of the maxillae is fractured through the infraorbital margin about the maxillary malar junction and infraorbital foramen and below the bony vestibule above the alveolar ridge. The direction taken by the fracture lines in the maxilla and ethmoids constitutes a circle drawn around the bony vestibule. The entire block of bone within this circle is thrust posteriorly. In this type of fracture if the cribiform plates are not fractured, the treatment of choice is to enter both antri through the canine fossa so that one may mold the bones forward and upward. Sometimes a gauze pack in each antrum for three weeks will maintain the proper position. When this does not suffice, one may be able to force the bones forward by means of a steel wire passed through the bone at an appropriate point to be looped in a projecting wire in a head cap of plaster. (2) The second type of fracture runs transversely—the inferior part of the superstructure of the maxilla along a more or less transverse plane above the alveolar ridges, and the transverse processes of the maxillae through the lower antral region. (3) The third classic fracture line runs high through the orbits and crosses the frontal processes of the maxilla, the lateral borders of the ethmoids, the pterygoid plates of the sphenoid and temporal processes of the zygoma. As a rule, a complete separation of all of both maxillary bones from the base and the skull occurs.

In many ways, the principle of treatment of the second and third classical types of maxillary fracture is identical. When the body of the mandible is fractured, it has long been known that if the maxillae were not fractured and the teeth were present the maxilla formed an admirable splint for the lower jaw when the lower teeth were fixed to the upper teeth. It has not been so generally recognized that the same principle in an adverse manner may be applied to a fracture of the maxilla. In other words, when the lower jaw is intact, it may be used for a splint and for support to hold the upper jaw intact. In such a case, if the lower teeth are wired to the upper teeth, it neces-

sarily follows—when one holds the lower jaw in its proper position—that the fractured jaw must unite with the teeth in occlusion.

In the past, for the care of fractures of the second and third



A B

FIG. 7. A, head cap made from a felt hat with very heavy elastic bands on the sides to elevate the lower jaw into proper position. The lower teeth should be wired to the upper teeth. B, example of a severe crushing injury of the nose and upper jaw in which the lower jaw was pushed into position and held there by means of a steel wire attached to a heavy projecting wire which was buried in a plaster head cast. A wire was also placed through the nasal bones to hold them together. Although it is not shown in the photograph two dental rolls were placed over the nasal bases to hold them together.

classical types just discussed, many complicated splints have been used. The principles of these splints was to fix the teeth to some type of arch with attached lateral arms which were reversed on themselves after they had been projected forward past the corner of the mouth. The reversed lateral arms were then fixed to a plaster or leather head cap. In other words, the upper jaw is held fixed upward in normal position when the arms of the splints are attached to the skull appliance. It is difficult to adjust splints of this type to the proper level. Thus, if the lower teeth are not placed in occlusion with the upper teeth, when union occurs, one is likely to find that the occlusion has been altered.

Recently we have used a simpler method than the preceding. The method assures proper occlusion of the teeth after healing has occurred. At first, no effort is made to replace the displaced bone. After most of the swelling and edema of the internal nose has disappeared (in about ten to twelve days) when the patient is able to breathe freely through his nose, one may replace the lowered max-

illary fragment. Immediately after the injury, and until free nasal breathing is established, the nose is irrigated with a saline solution to which some vasoconstrictor chemical has been added, every two or three hours. When the air passages through the nose have become clear, the upper teeth are wired to the lower teeth. A skull cap is placed over the skull. A chin cup is placed beneath the chin or body of the mandible. Between the chin cup and skull cap are placed rather strong elastic bands—two on a side. These bands are placed in such a manner that the chin and the body of the mandible are lifted upward. (Fig. 7A.) The principle is to use the mandible as a splint for the maxilla. This method assures proper occlusion and if the elastic bands are tightened sufficiently, the upper jaw is brought into proper position rather quickly.

Occasionally, a child or an adolescent girl will complain of this method as being rather uncomfortable. In several cases of this type a plaster skull cap has been placed about the head. Very fine steel wire was then run through the tip of the mental part of the mandible. To a very stiff wire placed in the head cast so as to project forward, the fine steel wire was attached. (Fig. 7B.) By this means, the upper jaw can be efficiently held at any point one wishes.

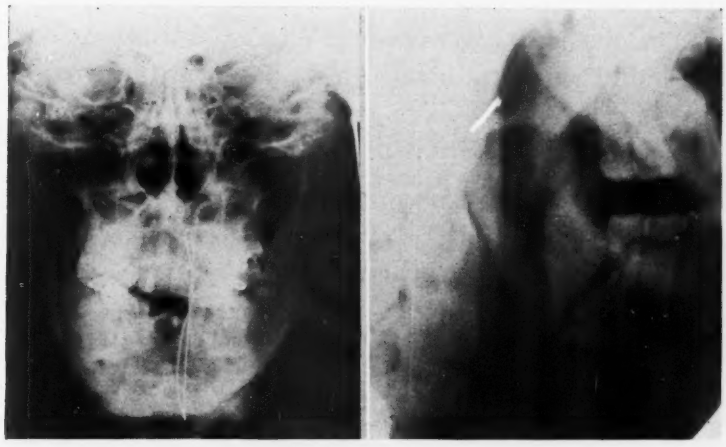
### FRACTURES IN THE MALAR REGION

The body of the malar bone not uncommonly is driven backward and impacted. When the direction is somewhat downward, the bone may impinge upon the coronoid process and the ramus of the mandible and prevent the mouth from opening. The orbital box is changed in shape. Very commonly the eye globe drops downward and somewhat backward. When one cannot replace the malar bone by inserting a screw elevator through a small opening in the line of fracture, one may obtain replacement by inserting a long, slender bone elevator into a small opening at the upper part of the temporal ridge, thence following the bony wall of the fossa to engage the posterior wall of the bone so that it can be pried forward, or by introducing a sound into the antrum through the canine fossa after which the bone is pried into place.

### RECENT FRACTURES OF THE MANDIBLE

A large variety of dental splints have been recommended for use in the management of fractures of the body of the mandible. But when there has been no bony loss and the upper jaw has not been fractured, for the vast majority of fractures of the mandible dental

splints are unnecessary. The principle of using the upper jaw for a splint to hold the lower jaw in position after the lower teeth are wired to the upper teeth is the most simple method. A bilateral fracture of



A B

FIG. 8. A, example of a bilateral fracture of the mental region which was held in place by means of a circumferential wire placed about the mandible and up over the maxilla in the subnasal region. B, example of a fracture at the angle of the mandible in which the third molar holds the ramus back in proper position.

the submental region is particularly difficult to hold in place just by simply wiring the lower teeth to the upper teeth because of the spasm of the geniohyoglossus muscles. In such cases one may resort to placing circumferential wires entirely around the body of the mandible after which they may be passed posteriorly to the alveolar ridge, through the palate and across the floor of the nostril just above the maxillary bone and then downward beneath the upper lip. (Fig. 8A.) When the palate is very high, one may have sufficient space to pass a wire above the apex of the incisors through the upper alveolus. By these methods the mental fragment of the mandible can be held firmly upward in apposition with the maxilla.

Fracture at the angle is sometimes difficult to treat properly. The main difficulty in such a fracture arises when the fracture line is posterior to the last occluding molar. When this happens and union occurs, the patient does not open his mouth normally. When the third molar is present, if the ramus fragment impinges against the tooth and is held from being pulled forward by it, the third molar should not be removed but should be left in position for a period of about three weeks for the purpose of maintaining the position of the ramus after the lower teeth are wired to the upper teeth. Usually

after about three weeks the soft tissues about the fracture will have become firm enough to hold the distal fragment in place. (Fig. 8B.) Now with care, one can remove the third molar to prevent its continued action as a foreign body. Usually this is not difficult as it will be found to be considerably loosened. When the third molar is absent or does not hold the ramus downward or backward, the most efficient method is to fix the ramus in its proper position by means of a wire passed through the posterior border of the ramus. The wire is anchored to a plaster skull cap. To expose the posterior edge of the ramus a small incision is made posterior to the angle of the jaw. After a small hole is drilled in the bone, a silver wire is passed through the hole. This wire is looped over a projecting heavier wire extending from the region of the mastoid part of the cast. To unite the ends of the bones by direct wire usually leads to sequestration about the wire which tends to interfere with union.

Because of the close attachment of the internal pterygoid internally and the masseter externally, fracture of the ramus usually shows little or no displacement. Therefore, one usually has no trouble in taking care of fractures across the ramus if one simply wires the lower teeth to the upper teeth. By this method, good position ordinarily will be obtained.

When the condylar neck is fractured, it is usual for the condyle to be pulled forward somewhat by the external pterygoid muscle. As a rule, however, if the lower teeth are wired to the upper teeth when union occurs, the function will be satisfactory. Rarely, one sees a fracture dislocation of the condyle. When the fracture line is rather low adjacent to the ramus, open reduction is satisfactory. When the fracture line is high, possibly one is wiser if the condyle is removed. Reduction is almost impossible to maintain.

The simplest and best method of handling an edentulous fracture of the body of the mandible is to circumscribe the lower jaw and a superimposed splint or lower denture if it has not been lost or broken.

It is not possible to wire the lower teeth to the upper teeth in children as a rule. The deciduous teeth do not withstand traction well. Nor is their shape such that wires ordinarily will stay in place about the neck. Therefore, in fractures of the jaw in children it is sometimes necessary to make use of a dental splint which is cemented to the teeth.

When the tooth necessary for superimposed intermaxillary wiring is absent, a horseshoe shaped half round heavy wire of German silver may be wired to the remaining teeth of either upper or lower jaw or

both. By passing crosswires over the half round wires proper fixation may be obtained.

### TREATMENT OF HEALED TRAUMATIC BONY INJURIES OF THE FOREHEAD, NOSE AND UPPER JAW

The healed bony lesions of the forehead, the nose and the face seek correction as a rule because of the contoural defect caused by either displacement or loss of bone. The healed bony lesion of the lower jaw region may show either a contoural defect, a loss of continuity or a malocclusion due to malunion.

When a healed depression of the forehead is symptomless, in my experience as a general rule the best correction is given when superimposed skin flaps are turned back and a properly fitted cartilaginous inlay graft is inserted. The same statement applies to the rebuilding of the supraorbital ridge. McIndoe, however, is rather partisan to bone. He used the inner cortex of the ilium for forehead depressions and the rim of the ilium to build out the supraorbital ridge. All evidence of infection should have disappeared at least three months previously.

### FRACTURE DISPLACEMENTS OF THE NASAL BONES

The objective in repairing healed nasal bone fracture displacements is to place the nasal bony arch in the midline, to straighten the cartilaginous arch and to provide a free airway. This should be done as soon as possible.

For healed lateral nasal displacements and curvatures of the nasal arch and septum the best results are obtained when the nasal bones are freed from the maxillary processes and, if necessary, the nasal septum is treated by judicious cartilaginous section or submucous resection or freeing of the septum at the nasal spine. When one side of the nasal arch is too long, it may be well to remove a wedge of bone from the base of the longer side. When the nose tends to return to its former position after mobilization, sometimes a through-and-through steel wire looped over an opposite tooth and over a piece of rubber tube or dental roll on the side to which the deviation tends will prove efficient. At other times, it may be wiser to apply definite lateral immobilization by means of a head cast from which projects a wire which lies along the lateral side of the nose. This is worn until union is sufficient—during the second and third weeks after immobilization.

For the correction of healed crushing fractures of the nose as a rule the mandate is elevation of the bridge or bridge and tip by the insertion of an implant of cartilage. If the tip is depressed, a right

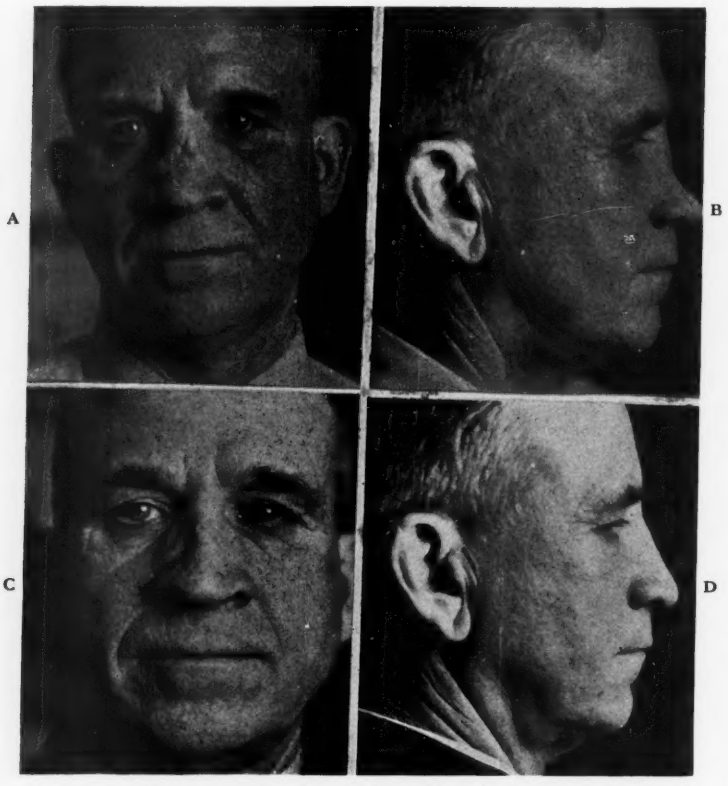



FIG. 9. A and B, example of an old crushing fracture of the nasal bones in which it was necessary to place two pieces of cartilage to obtain a good contoural result. The upper cartilage was a right angled cartilage. C. and D, final result.

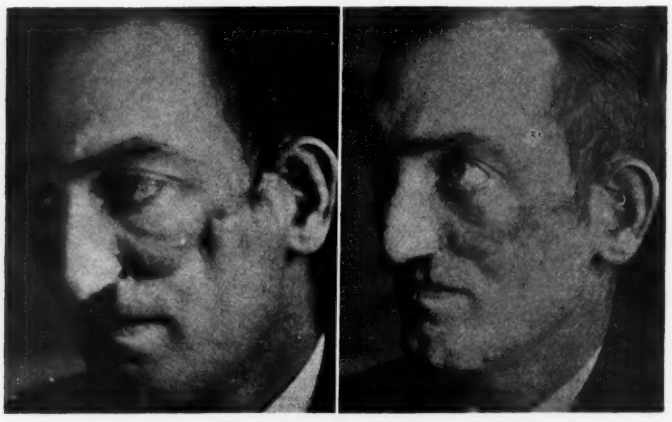
angled cartilage is indicated; if not, a dorsal straight implant is sufficient. Not uncommonly, two superimposed cartilages are necessary. (Fig. 9A and B.) When the frontal processes and the lachrymal crests have been splayed outward over the maxilla and into the orbit, the nasal arch may require cross-cutting at the base followed by medial replacement and the splayed out bone projecting into the orbit should be chiseled or rongeured away. This should be done before the cartilage is transplanted. Sometimes, it is wise to transplant the cartilage at separate sittings if a superimposed piece is necessary. This will depend upon the degree of difficulty in mobilizing the soft tissues. The septal deformity is corrected in a manner similar to that just discussed under healed lateral nasal displacements.

Whether or not one does a cartilage transplant in combination with another procedure on the bones or the septum will depend upon whether or not the combined operation is likely to result in contamination of the bed in which the cartilage has to lie.

Usually in healed malar maxillary distortions in addition to displacement of the malar bone inward, downward and backward, there is evidence of serious displacement and comminution of the maxilla which usually results in destruction or depression of the infraorbital plate causing downward displacement of the globe of the eye. The first decision to make is whether treatment is to begin with an effort at disimpaction and elevation of the malar maxillary displacement or whether treatment by camouflage is preferable. As a rule, some camouflage therapy will be necessary even if replacement is done because complete replacement may not be possible. For disimpaction a double approach is as a rule necessary; (1) from beneath the upper lip across the anterior maxillary wall and (2) through an incision in the upper temporal region so that a chisel may be passed posterior to the temporal muscle to a point behind the malar bone. These approaches also allow one to pry the bone forward. To hold the bone forward and upward, it will be necessary to pass a fine steel wire through the bone to be looped over a heavy projecting wire laid in a plaster cast head gear. The best camouflage treatment as a rule is obtained by filling out the contoural defect of the cheek with implants of cartilage. (Fig. 10A and B.) When the infraorbital plate has been lowered, implants of cartilage should be inserted to elevate the infraorbital floor. When an enophthalmus is present, sometimes some improvement can be given by inserting cartilage posterior to the globe and external to the muscles controlling the globe. To do this, the approach devised by Killian is necessary. When the malar bone is down far posteriorly and medially and impinging upon the coronoid process and the ramus, it may be advisable to remove the bone.

The well known "dish-face" deformity caused by a healed nasal ethmoidal maxillary fracture displacement is difficult to correct. Satisfactory elevation of the impaction is hardly possible but there are several procedures of the camouflage nature which may give quite remarkable improvement both in appearance and in function. It is stated by McIndoe that sometimes before six weeks have passed, this impaction may be advanced as much as one-half inch by means of pulley traction. Usually a submucous resection will be necessary. Often the tear ducts are blocked. By removal of the intervening bony

partition and an appropriate plastic operation the tear sac may be drained into the nose. The splayed frontal process of the maxilla and the lachrymal ridge may be chiselled and rongeured away. The bony



A B

FIG. 10. A, depression defect in the left cheek and maxillary region in which the depression was filled out by a cartilage transplant after two flaps had been laid back. B, final result.

arch of the nose can be built up by cartilage implantation. The depressions about the alar bases and over the antrum if present may be filled out by judicious insertion of cartilaginous implants of the appropriate size and shape.

### LOSS OF BONE

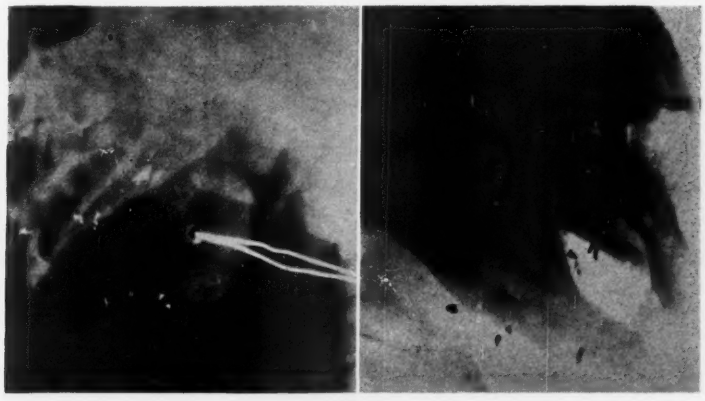
When there has been loss of maxillary bone if the loss is only of the alveolus or the lower part of the super structure is not large, a dental prosthesis without any reconstruction of the soft tissues usually is sufficient. But when the loss of bone of the superstructure is greater than one-half, it will often be necessary to add additional epithelial lining either by means of a skin graft or a skin flap so that not only adequate masticating power may be provided but the contour of the face may be corrected by prosthesis.

### BONY LOSS OF THE MANDIBLE

Two types of bony loss of the mandible are seen: parallel loss and rectangular loss (loss of continuity). Parallel loss of the mandible along the lower border causes a contoural defect which may be corrected by the implantation of cartilage. When the loss is intraoral, it should be compensated for by prosthesis.

Loss of continuity of the mandible is always associated with considerable disfunction because the muscles of mastication tend to

lose their normal co-ordinated activity. Scar tissue adds to the distortion. When the loss of continuity is not greater than a few centimeters, the method of Delengeniereor Kazanjian of placing multiple



A B

FIG. 11. A, roentgenogram of a defect in the body of the mandible due to a gunshot wound. The ramus is being held back by a wire placed through it and inserted into a projecting wire at the posterior part of a head cast. B, *x*-ray one year after a bone graft was inserted.

small pieces of bone and periosteum across the defect may be quite applicable. During the last War of thirty-eight patients operated upon by this method in the United States Army, twenty-seven (71 per cent) were successful.

Defects in the lower jaw region complicated by a fairly large loss in bony continuity have been repaired in four different ways: (1) by free bone graft; (2) by bone transplanted in a pedicled flap from a distance; (3) by sliding a section of bone from a neighboring fragment without freeing it from its soft tissue attachments; and (4) substitution of prosthesis for loss of about one-half of the mandible.

A free bone graft is most applicable when the surrounding soft tissues are sufficient or easily transferred and when the defect is a long one of the body and a part of the ramus of the mandible. The graft may be taken from a rib (Fig. 11A and B) or the crest of the ilium. The crest of the ilium is preferable when the angle is absent.

Often time can be saved when it is necessary to add soft tissue lining and covering as well as structural support if all three are transplanted together. A fairly accessible area from which to obtain the bone and necessary soft tissue is the clavicular area. A split half of a longitudinal section of the clavicle is buried in a skin flap doubled upon itself.

When the body of the mandible is long on one side and there is also a soft tissue defect, and especially if the loss is in the mental region, an oblique, longitudinal segment of the lower part of the long body fragment with soft tissue attachment may be slipped across to bridge the bony defect. Later, after union is obtained, the contour of the face may be improved if the soft tissues are rearranged and possibly replaced to nearly their former position.

If the whole region of the position of the half mandible that has been lost is relined with a skin flap, it is possible to hold the intact half of the jaw in fair position and to bolster out the contour of the cheek on the defective side by building an intraoral prosthesis in lieu of the loss of the mandible.

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## DISCUSSION OF PAPERS OF DR. CAMERON AND DR. PADGETT

Fenwick Beekman (New York City): I feel that I am incompetent to discuss this admirable paper of Dr. Padgett. As a general surgeon, I am not trained in maxillary or oral surgery; however, we see in New York City, especially in our public hospitals, a great many late results of trauma. In a large city like New York we do not get the fresh accidents that the smaller cities throughout the Union do, as most of our patients are first treated in the country and then they are sent to us.

I picked out of my collection of lantern slides four or five illustrations which I think will demonstrate some of the things that Dr. Padgett has spoken about today.

The first is that of a boy, about seven years of age, who came into the hospital after having been in an automobile accident on Long Island. He was taken to a local hospital and there the surgeon débrided his entire lower lip and chin, leaving a large elliptical wound from which he drooled a large amount of saliva the entire time.

This is the mistake that is made so often, instead of tacking together whatever tissue there is, even if it be contused and lacerated, so that we would have something to work on, it was excised completely, leaving very little tissue to work with; however, we were able to undermine and reconstruct a lower lip.

I meant later on to fill in the chin with a flap from his chest or from his arm, but the parents, who were very ignorant people, insisted upon removing him from the hospital and I have never seen him since then.

My second case was not a case of trauma, but it represents very well the need of using pedicle flaps in restoring a face. This was a child in Bellevue Hospital, who had a noma of the face. It was symmetrical. A year later, infection having been overcome, she was handed over to me so that I could do what I could with her.

Not only had the soft tissues of the face necrosed but also a large amount of the lower jaw. She could retain no saliva in her mouth. It was dripping out continuously. I raised a flap from the chest on the right side and brought it up to form a lower lip. I then closed the nostrils with the tissues that were present and brought another pedicle flap from the right arm and made an upper lip. Then, to fill out the nose, I raised a pedicle flap from her axillary region, fastened it to her wrist and brought it up to build the nose.

Having gotten the flaps in position, they were very large and ungainly, so I commenced to mold them into position.

I did not bring the slides showing the intermediate parts of my procedure, but I have the almost final result which we will now show you.

This was the girl taken a year ago. She is now sixteen years of age and since these pictures were taken, I have taken some fat out from beneath her chin. Last year I attempted to put cartilage in the nose but, unfortunately, every time I operate on her now, she develops an erysipelas, as she did in this case, and the cartilage sloughs out; however, she is better-looking now than she was in the first pictures.

I think we owe a debt to Dr. Padgett for bringing these things up because I believe general surgeons should know something of plastic surgery.

HARRY E. MOCK (Chicago, Ill.): Dr. Cameron's paper is exceedingly timely and since he paid quite a compliment to St. Luke's Hospital in Chicago, and Dr. Hirsch, I think some one of us should acknowledge the compliment and bear out his statements.

In 1924, I think, occurred the last death we had from blood transfusion, by one of our best surgeons on a very important patient, and, following that, Dr. Hirsch developed the technic which you outlined. As one of the clinicians there, time and again I have tried to rush Dr. Hirsch on skipping the office hour, or something of the kind, but it is utterly impossible to get him to vary from the one hour and a half, and we have all come to agree that it is right and proper. Seldom does the patient require the blood transfusion

in such an emergency that we cannot give that hour and a half; and, when it is necessary, our salt and glucose are used until the time is up and we can transfer to a true blood transfusion.

I think that out in the country—I see a number of blood transfusions—only once have I seen a fatality, but I marvel at what they get away with sometimes, the short period of grouping the blood or of grouping and compatibility, and I think that this is one of the greatest contributions that has come before us, and it should be stressed—the care with which the blood should be chosen for these transfusions I also want to compliment the essayist on that last paper, too, for it was excellent.

ANGUS L. CAMERON (closing): I simply want to thank the discusser, Dr. Mock, for his very kind remarks.

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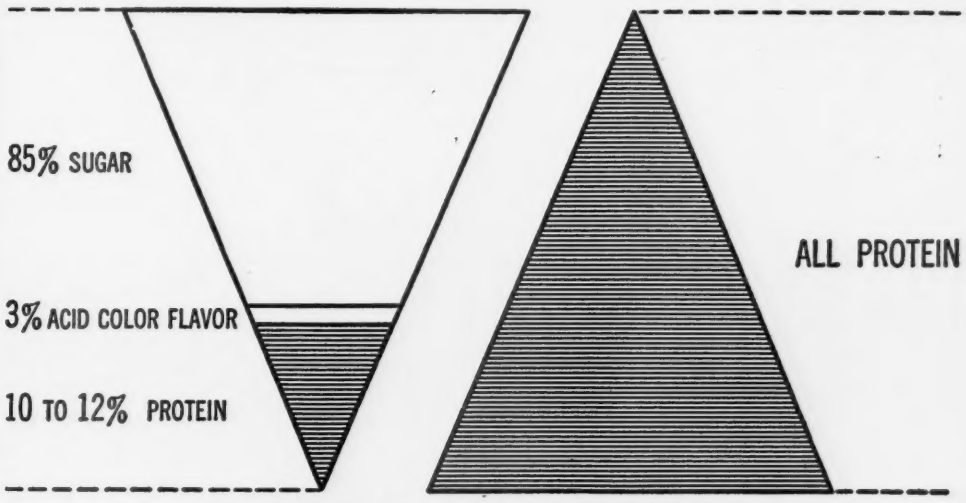


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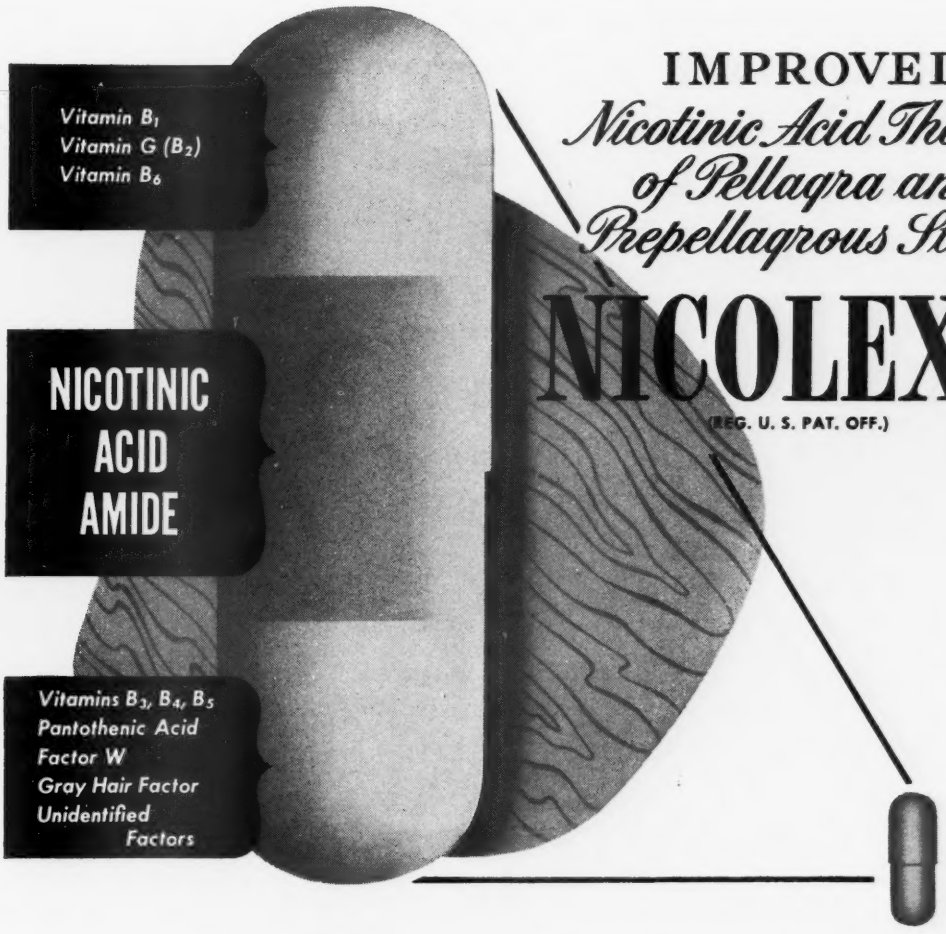


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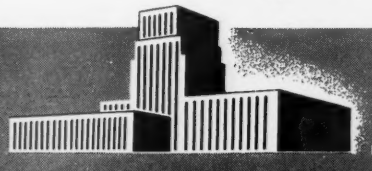

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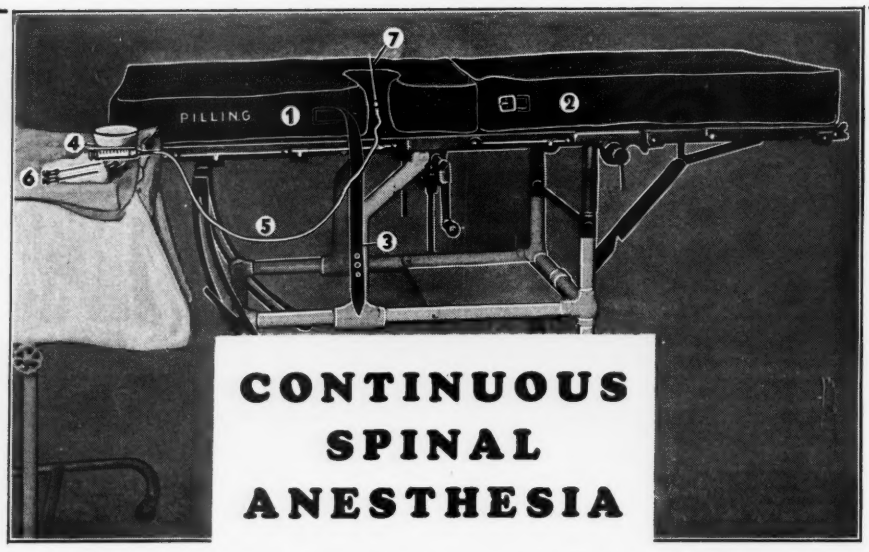


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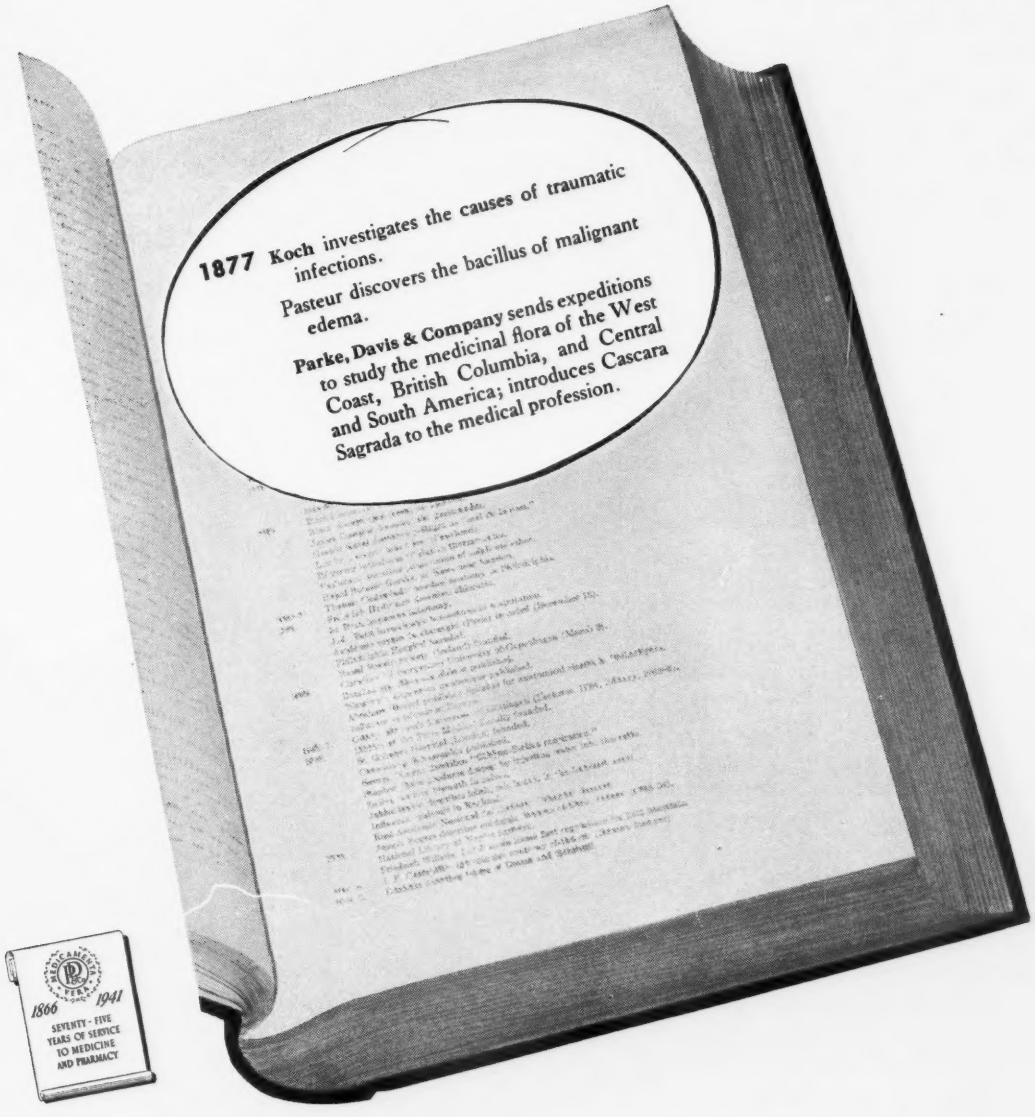
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*Louisville, Ky.*, 1941 (Secretary—COL. JAMES M. PHALEN, 1870 Wyoming Ave., N.W., Washington, D. C.)

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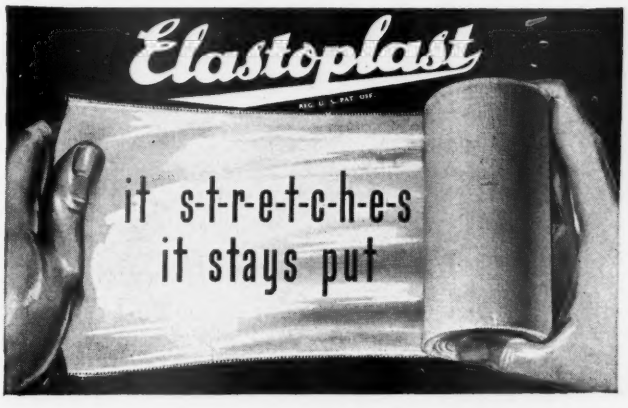


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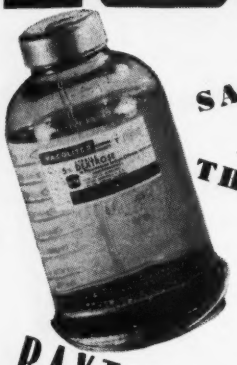

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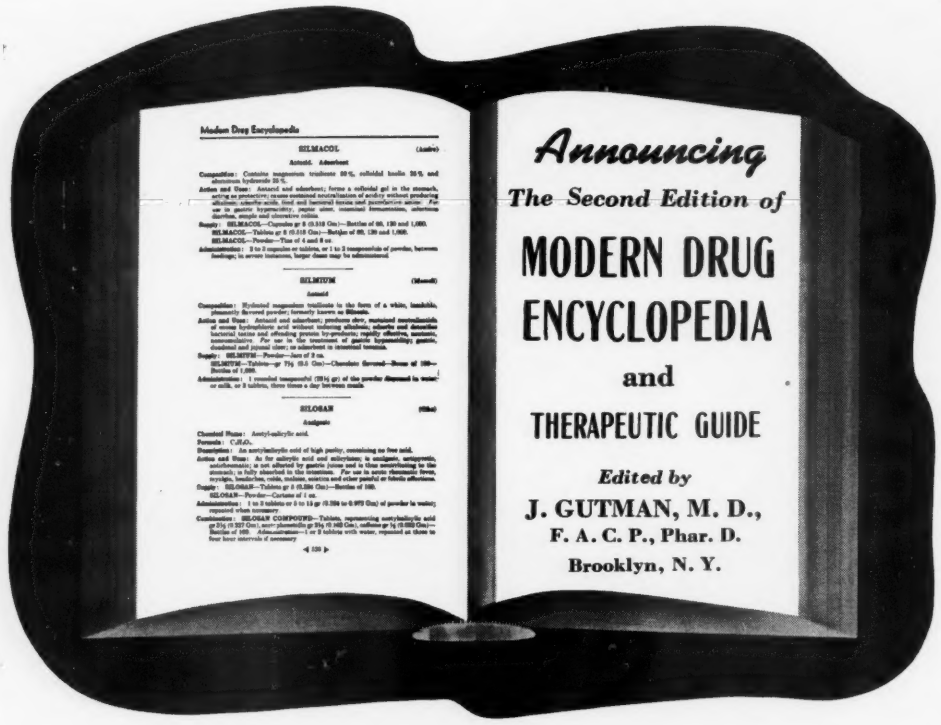


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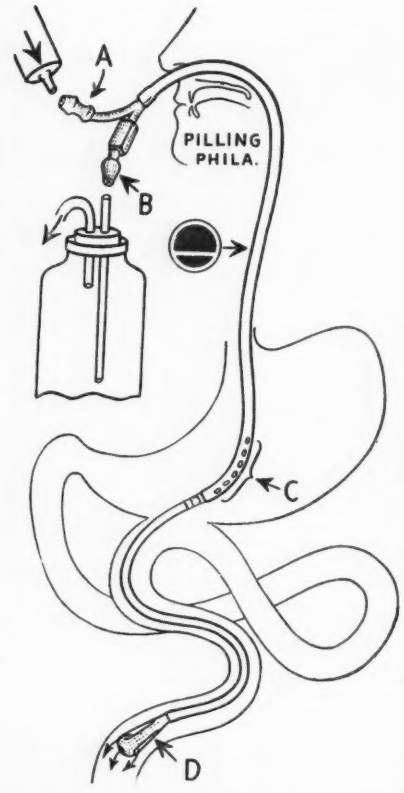


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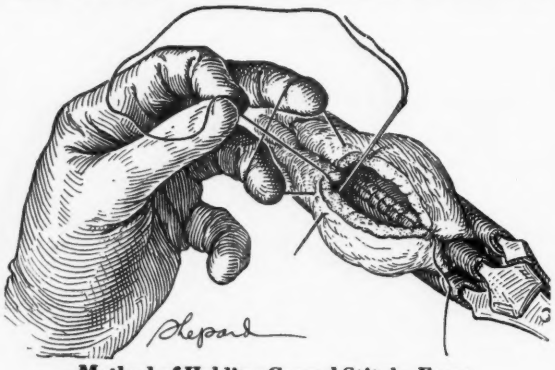

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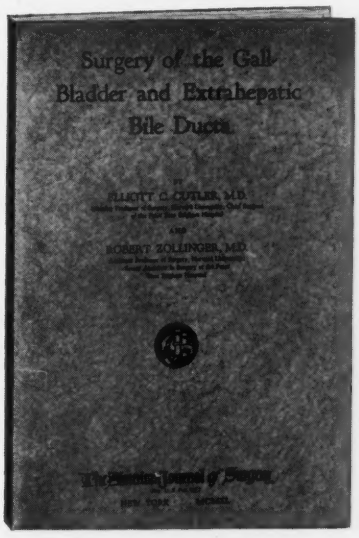


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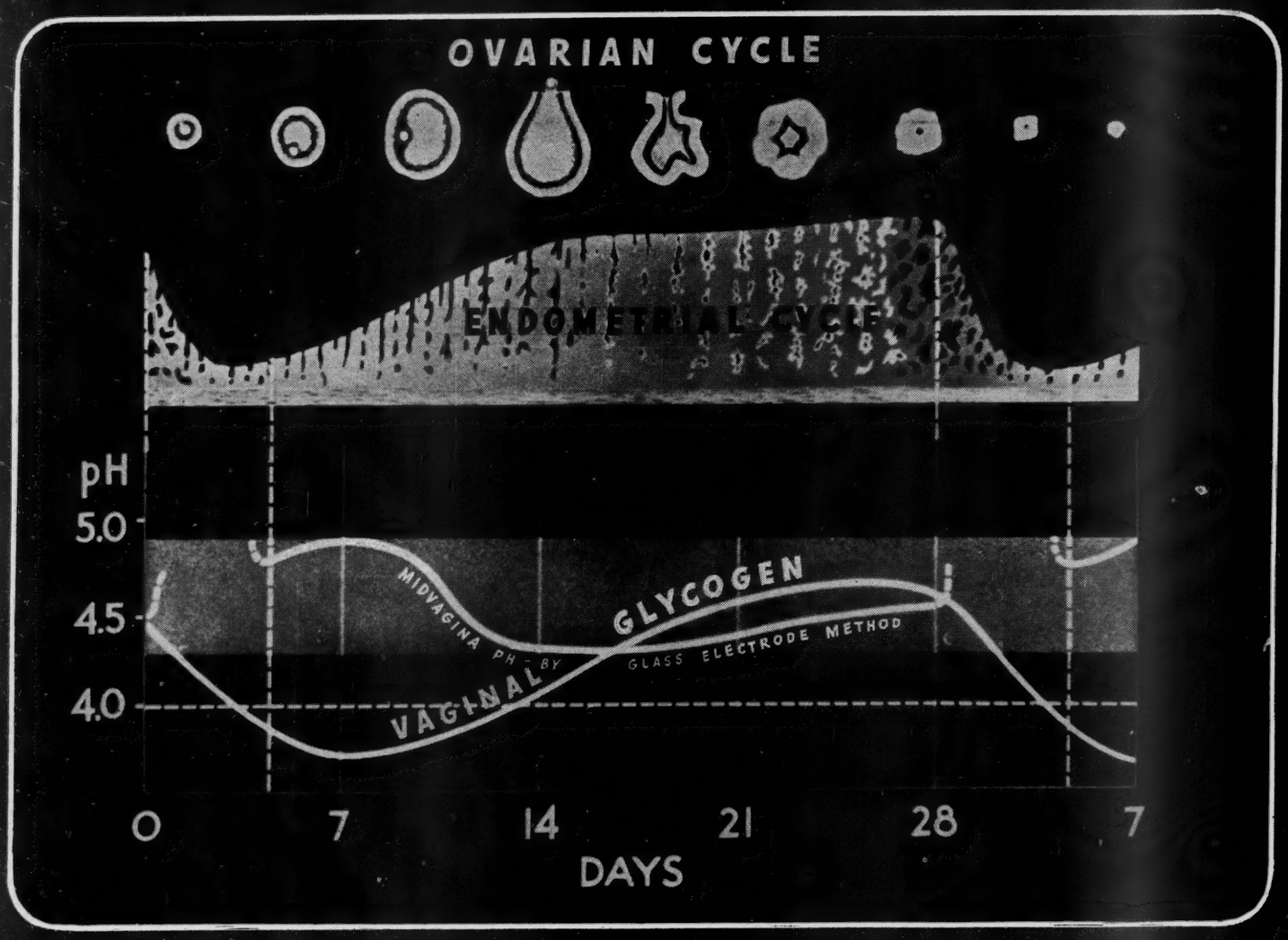


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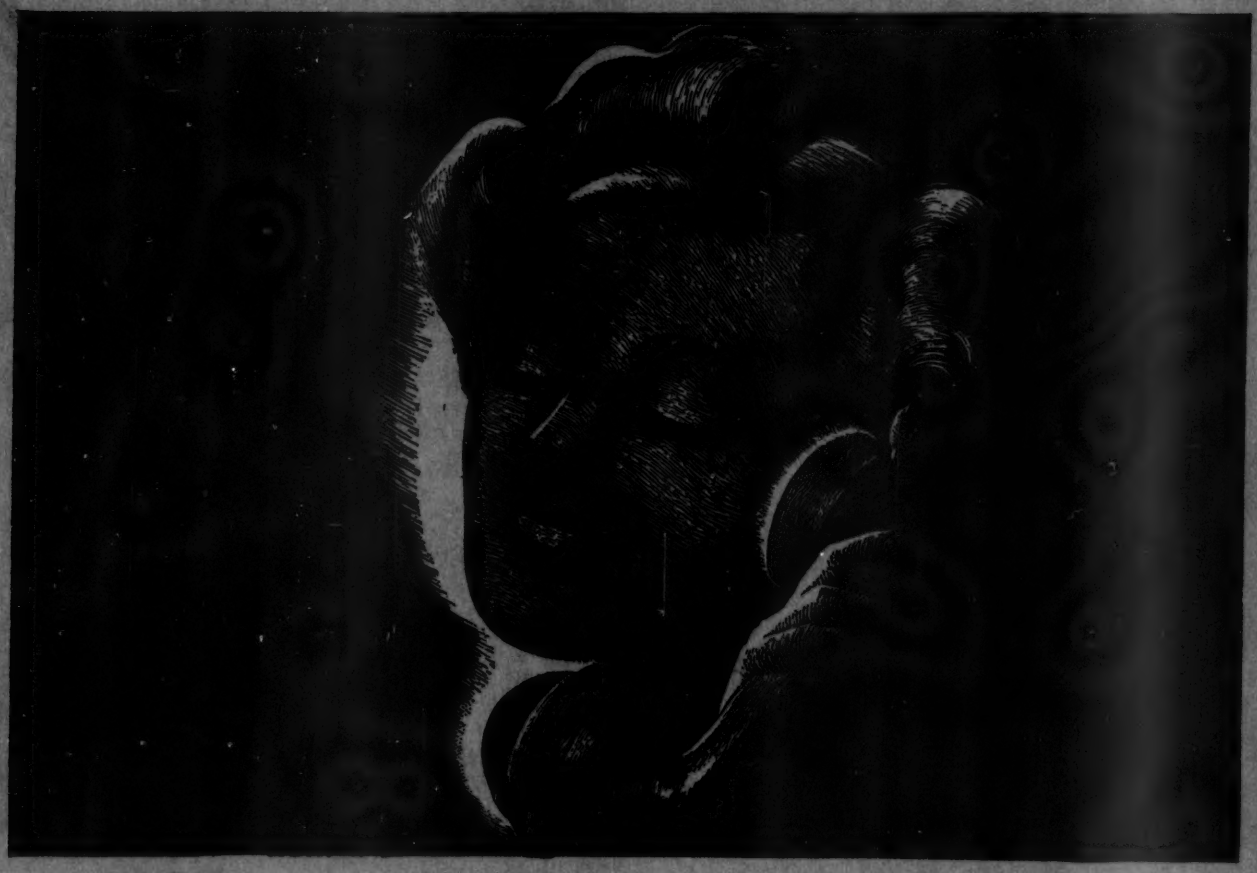

# *Thank You, Doctor, for* NUPORALS...

**Ciba's anesthetic throat lozenges, NUPORALS,* (containing non-narcotic Nupercaine) afford your patients prolonged relief from pain and tenderness of the mucous membrane of the throat and mouth and also diminish pharyngeal reflexes.**

**Your patients will thank you for giving them NUPORALS prior to the use of the stomach tube, or before any laryngeal or pharyngeal examination.**

**Available in boxes of fifteen and bottles of one hundred lozenges.**

**Additional information and samples upon request.**

* Trade Mark Reg. U. S. Pat. Off. Word "Nuporals" identifies throat lozenges of Ciba's manufacture, each lozenge containing 1 mg. of Nupercaine, "Ciba."

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